


Research Results Forum for Renewable Energy Technology and Resource Assessments

Public Workshop at the California Energy Commission (CEC)

September 3, 2014

UC San Diego

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UNIVERSITY OF CALIFORNIA

California Renewable Energy Center

9:00	Introduction and Overview
9:15	Integrated assessment of renewable technology options
10:15	Break
10:30	Assessment of Co-located renewable generation potential
11:00	Assessment of geothermal in under-served regions
11:30	Solar heating and cooling technology analysis
Noon	Lunch
1:15	California off-shore wind technology assessment
1:45	Technical assessment of small hydro
2:15	Biomass resources and facilities database update
2:45	Break
3:00	Assessment of sustainability for new/existing biomass energy
3:30	Biomass/MSW gap assessment and tech options for biogas clean-up
4:15	Future research recommendations
4:45	Closing

Introduction and Overview

California Renewable Energy Center (CREC)

- Funded since 2002 through the Energy Commission's Public Interest Energy Research (PIER) program.
- Currently funded through multi-year contract from the Energy Commission.
- Integrated multi-sector research center focused on the development of a sustainable energy future in California. The CREC is comprised of five renewable collaboratives: (a) Geothermal, (b) Biomass, (c) Small Hydro, (d) Wind, and (e) Solar.

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UC DAVIS CALIFORNIA GEOTHERMAL ENERGY COLLABORATIVE

STATE OF CALIFORNIA ENERGY COMMISSION

UC DAVIS CALIFORNIA BIOMASS COLLABORATIVE

UC DAVIS CALIFORNIA SMALL HYDRO COLLABORATIVE

UC DAVIS CALIFORNIA WIND ENERGY COLLABORATIVE

pier PUBLIC INTEREST ENERGY RESEARCH "Research Powers the Future"

UC DAVIS CALIFORNIA SOLAR ENERGY COLLABORATIVE

Scope of Work

To help meet California's aggressive goals set forth via AB 32 and the RPS, the Energy Commission retained the California Renewable Energy Center to:

(1) Update/refine existing renewable resource and technology assessments and databases.

(2) Provide renewable energy assessments that are integrated, comparative, and multi-dimensional.

(3) Address complex issues of renewable energy development and integration data needs.

(4) Conduct data-driven and science-based analyses to answer emerging renewable energy technology and economic questions.

(5) Support sate level policy making and achievement of California renewable energy goals.

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Integrated Assessment of Renewable Energy Technology Options

California has a long history of aggressively pursuing renewable energy – early adoption of RPS and greenhouse gas reductions (AB32).

It is now clear that many instances exist in which different renewable resources are co-located. How best to take advantage of this opportunity?

PURPOSE: Undertake an integrated assessment of the current state of development of each renewable technology *(Task 5)* and identify opportunities for coordinated development *(Tasks 2 and 5)*.

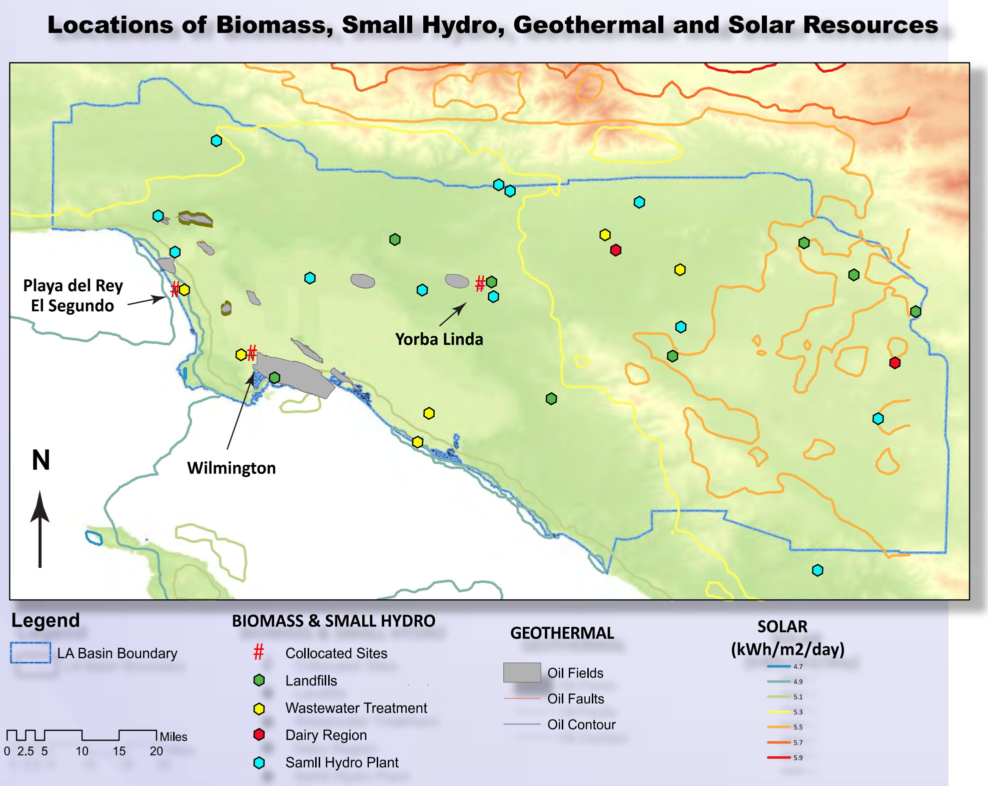
APPROACH:

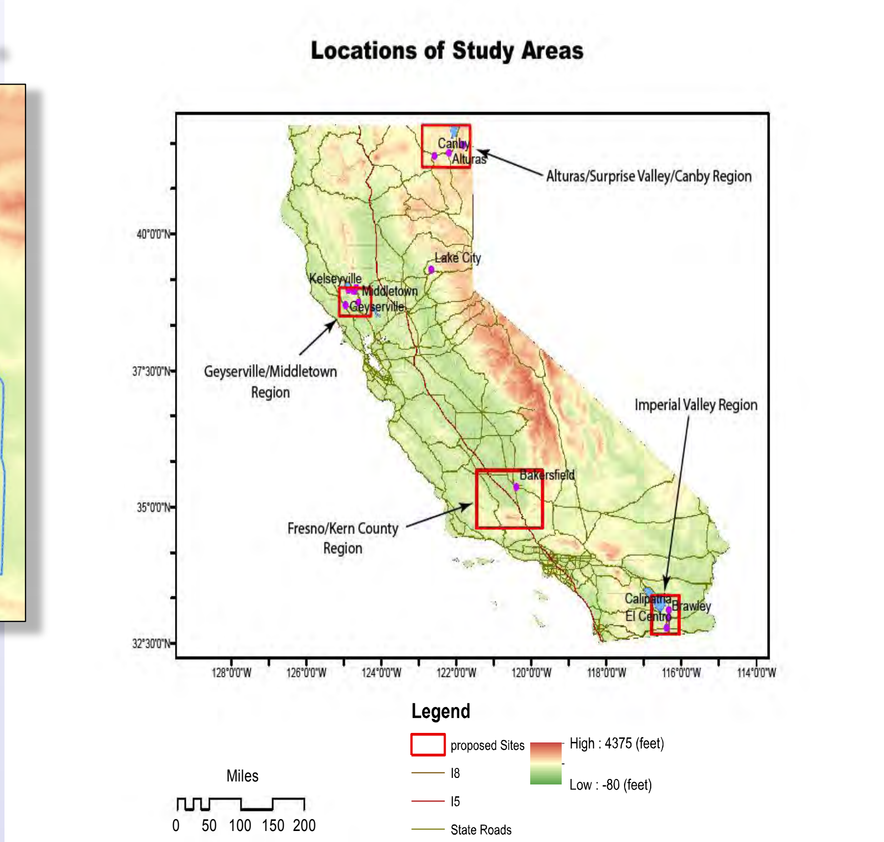
1. Determine current in-state technology capability, *vis-à-vis* state-of-the-art *(Task 5)*
2. Identify representative regions for resource assessments *(Tasks 2 & 5)*
3. Quantify resource base, and evaluate benefits and impacts of resource development *(Tasks 2 & 5)*

Because of California's diverse resource base and geographic characteristics, a two-part analysis was conducted.

Los Angeles Basin
(Task 2)

Statewide sites
(Task 5)





Organization of this session:

- Overview of solar, wind, geothermal and biomass technologies *(Task 5)*.
- Assessment of four statewide sites *(Task 5)*.
- Discussion of the Los Angeles Basin results later *(Task 2)*.

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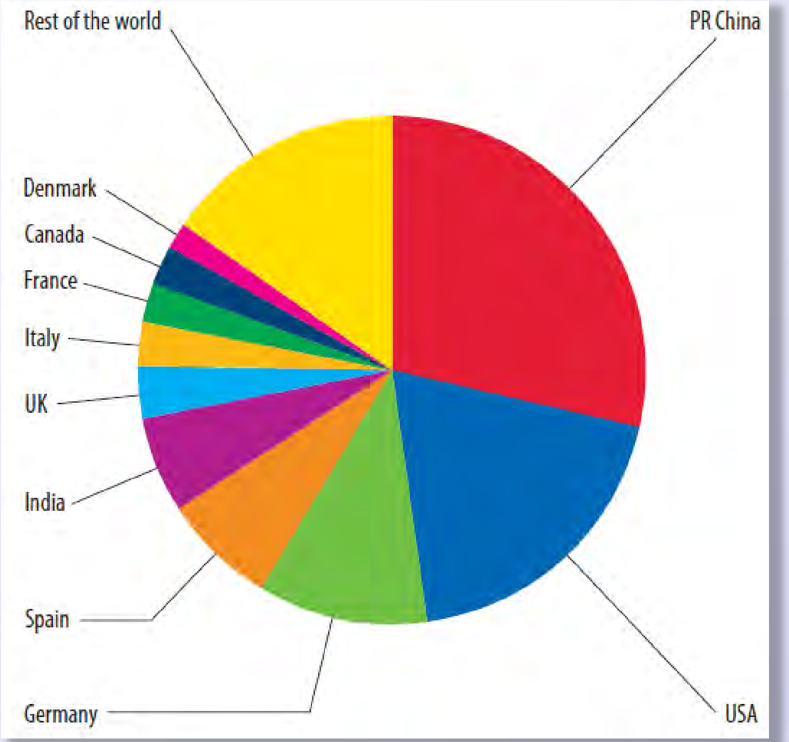
California Wind Energy Collaborative

Henry Shiu
Case van Dam

Wind Power: Industry Status

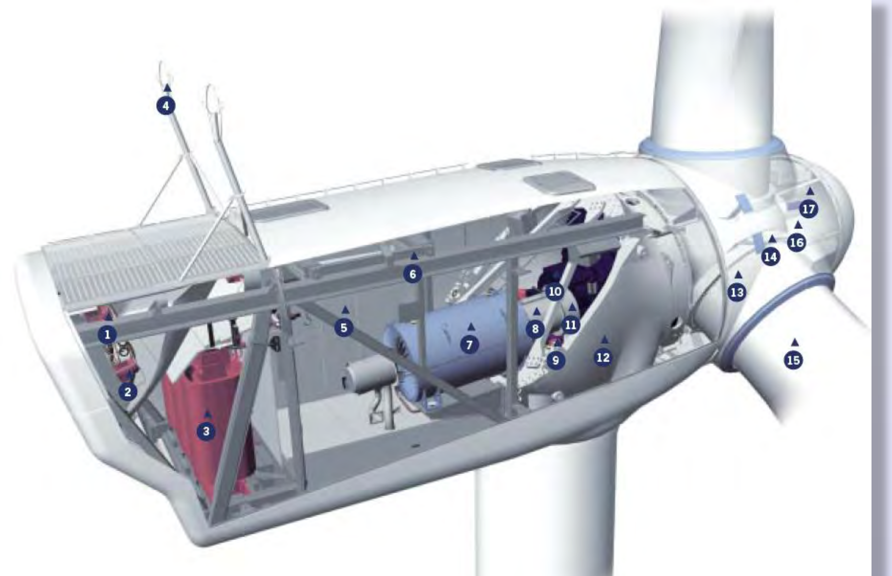
- End of 2013
  - Global: 318 GW
  - U.S.: 61 GW
  - California: 5,829 MW
    - State with 2nd most wind capacity
    - Most growth in 2013
- U.S. slow down in 2013
  - 2012: +13.13 GW
  - 2013: +269 MW
  - Driven by policy uncertainty – PTC volatility
  - 114.1 GW in queue



Source: LBL/DOE, GWEC

Wind: Technology State of the Art

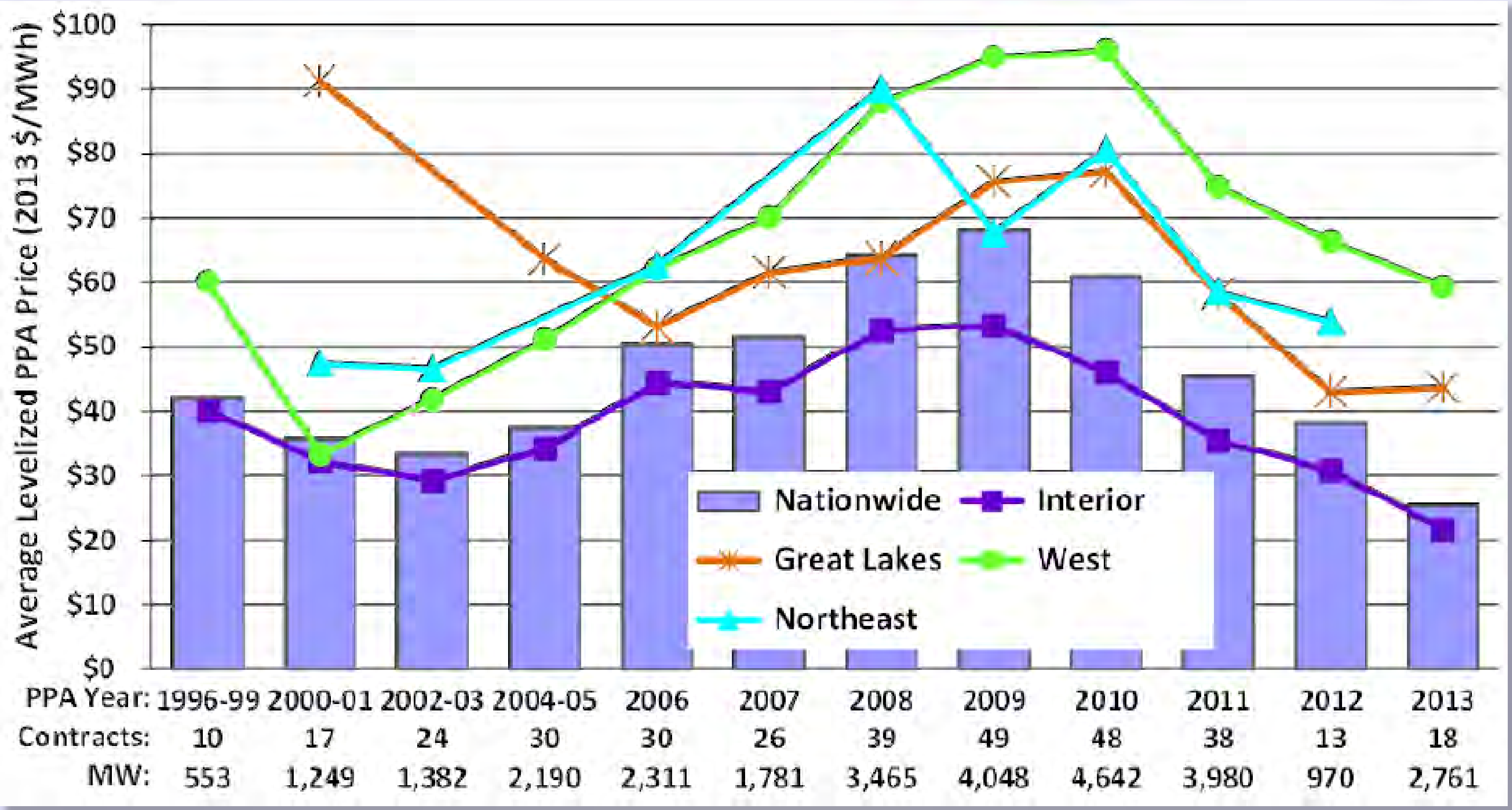
- 3 blade, horizontal access, upwind rotor
- Blade pitch for power regulation
- 1.5 – 6 MW
- 80 – 150+ m diameter
- Predominantly geared drivetrains, some direct drive
- DFIG or full conversion generators (AC-DC-AC) for partial or full variable speed
- Advanced power electronics provide grid support: voltage support, LVRT, ZVRT



Source: Vestas

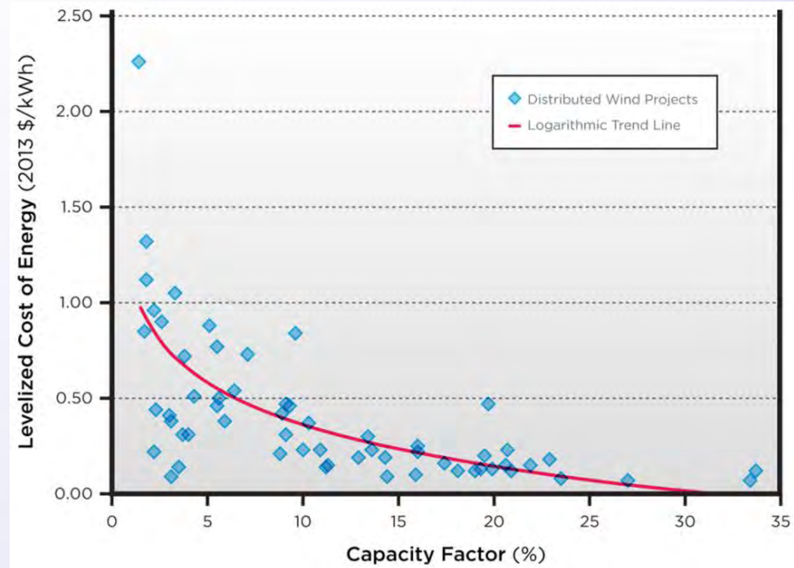
- Steel tubular towers
- Fiberglass blades, some carbon fiber

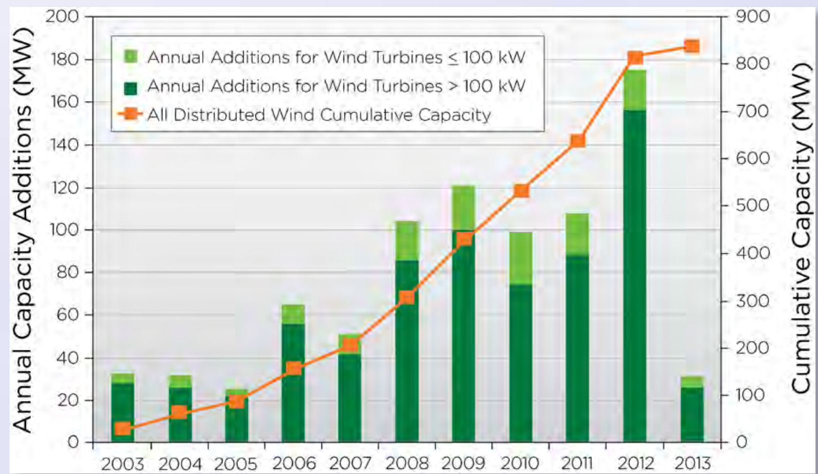
Wind: Economics – 2013 Price of Energy



Distributed Wind

- On-site or installed within distribution networks
  - Includes localized energy resources as defined by Governor Brown's Clean Energy Jobs Plan
- Small and utility-scale turbines
- End of 2013: ~65 MW in > 100 kW turbines, ~ 10 MW in ≤ 100 kW turbines
- New financing options such as PPAs have boosted the market
- Utility-scale turbines have sophisticated power electronics, but distributed interconnection requirements are limited

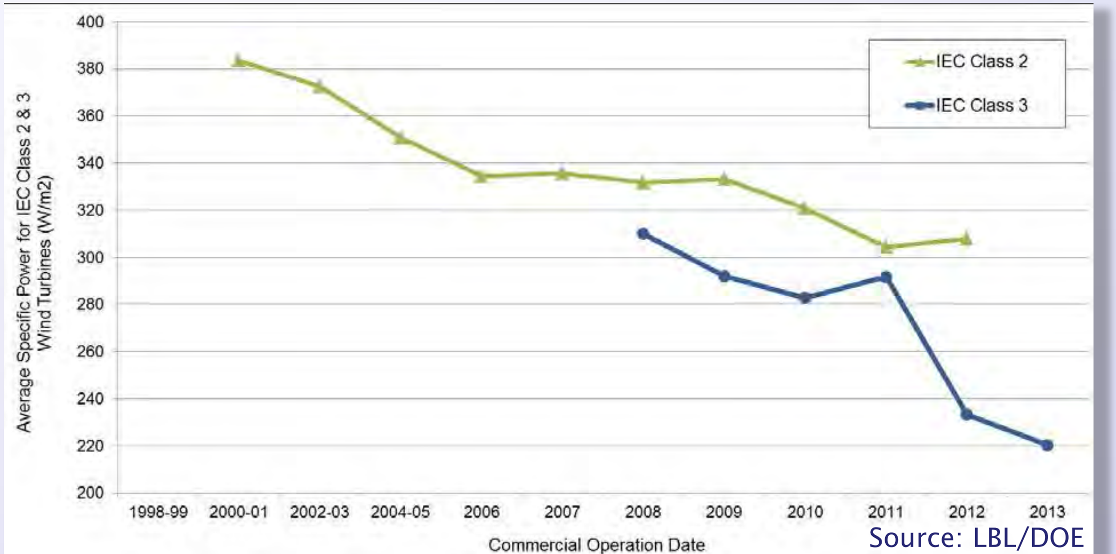




Source: "2013 Distributed Wind Market Report", DOE

Wind: Emerging Technologies – Bigger Rotors

- Wind turbine rotors are getting larger
- Example:
  - ca. 2002: GE 1.5 – 65m, 70.m, 77m
    - 452 W/m²
  - Now: GE 1.6 – 100m
    - 204 W/m²
- Intended for lower wind speeds (IEC Class III)
- Widely deployed in higher wind sites, presumably at lower turbulence sites



Source: LBL/DOE

- Long term impact on fatigue life?

Wind: Emerging Technologies – Advanced Towers, Turbine-Level Energy Storage

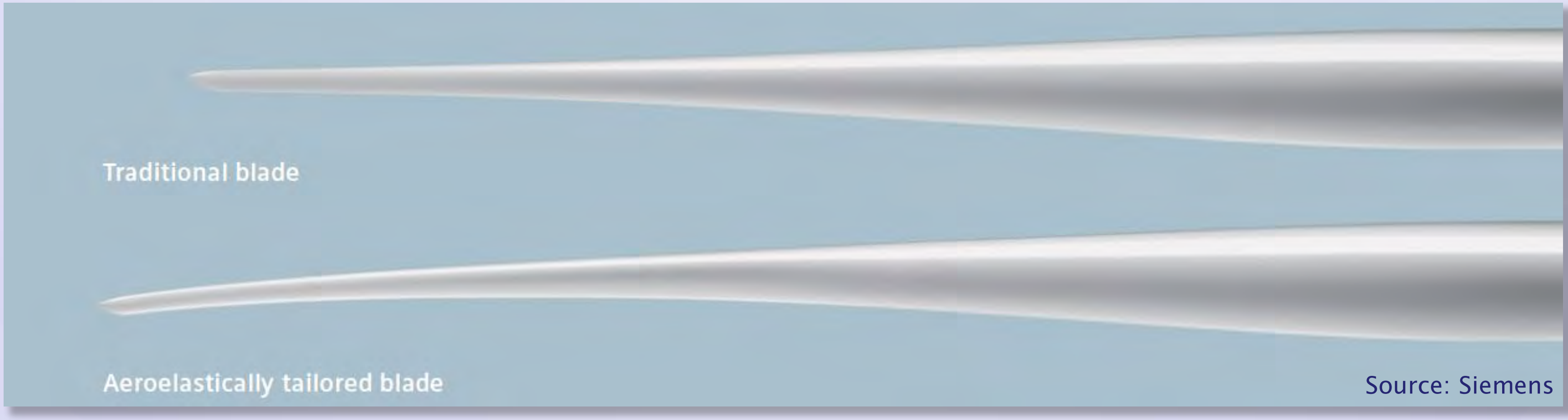
- Advanced towers
  - Hybrid steel-concrete
  - Spaceframes
  - Resolves transportation constraints, improves access to complex terrain
- Manufacturer-integrated, turbine-level energy storage
  - Marketed as lower-cost option to plant-level storage

Source: Bastgen

- Ramp control, power smoothing, frequency regulation

Wind: Emerging Technologies – Advanced Aerodynamics

- Active flow control
  - Devices/systems on blades such as flaps/ailerons, microtabs, morphing trailing edges, blowing/suction
- Passive innovations
  - Blunt trailing edge airfoils (flatbacks)
  - Aeroelastic tailoring
    - Sweep-twist, bend-twist blades



Source: Siemens

Wind: Integration Thoughts

- Small footprint
- Variable generation with uncertainty
  - Strong seasonal pattern
  - Strong diurnal pattern
- High penetration into grid
  - Short-term forecasting
  - Grid-level strategies
    - Coordinating with neighboring balancing authorities
    - Maintaining flexible generation portfolio
  - Next steps: curtailment, energy storage

- High penetration in distribution networks
  - Unlikely to occur in residential and urban environments
  - More likely in rural and industrial areas, but no significant concentrations in California yet
  - Power electronics compliant with grid codes, but distribution interconnection requirements may be less restrictive

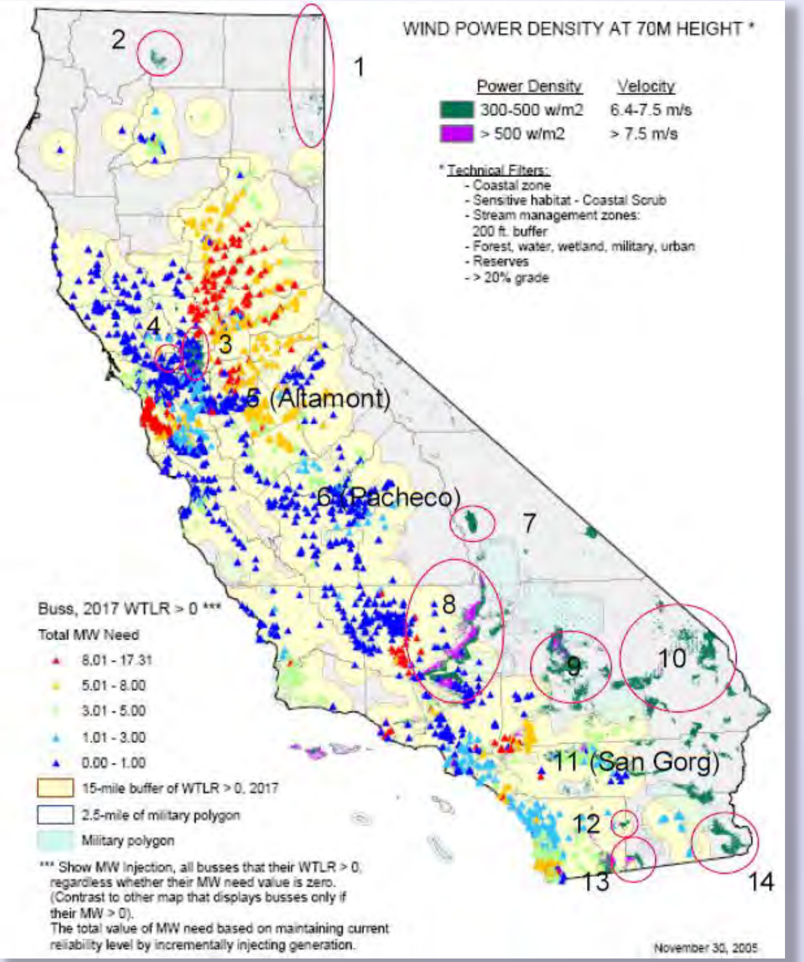
Wind: Preliminary Resource Assessment

California Wind Maps

- Developed by AWS Truepower for CEC
- Computational model calibrated with field data from selected sites
- Mean annual wind speed at 30, 50, 70, 100 m heights at 200 m spatial resolution
- Wind speed and direction distribution, mean seasonal and monthly wind speeds, shear

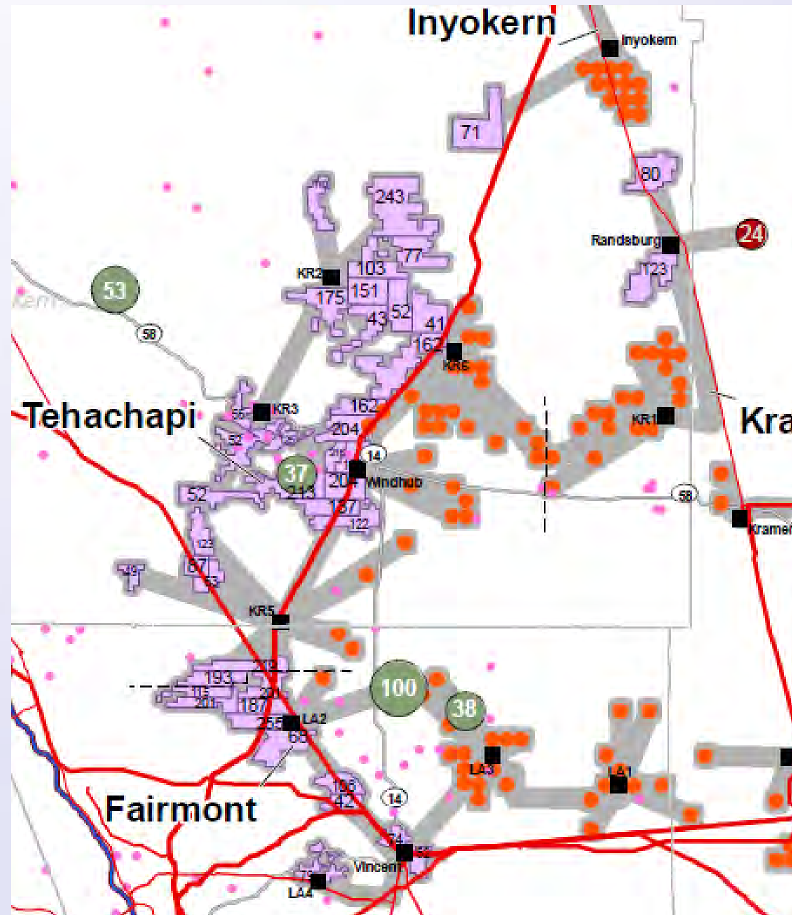
Wind Development Potential: CA IAP

- Part of IAP, studying benefits/impacts of RPS build-out scenarios (20%, 33% penetration)
- Performed by AWS Truepower
- Identified 11 regions with > 10 GW of new potential wind capacity
  - Warner, Montezuma, Solano, Altamont, Sequoia, Tehachapi, Western & Eastern Mojave, San Gorgonio, Jacumba, Yuma
- Factored in exclusion zones (e.g., environmental sensitivity, terrain, cost for transmission and interconnection)



Wind Development Potential: RETI

- Transmission planning study to support renewables growth
- CREZ's – renewables grouped by proximity, development timeframe, transmission constraints, economic benefits
- Exclusion filters applied
- Phase 1B (2009): 134 wind projects, 16,465 MW capacity



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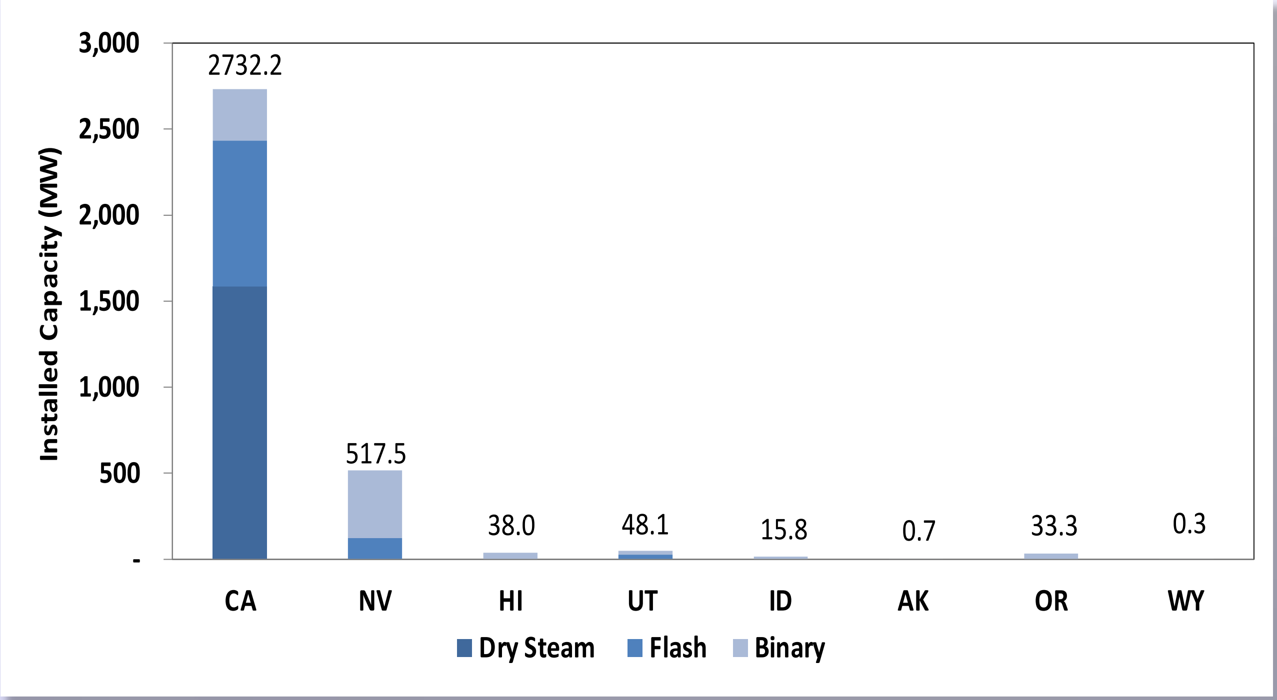
California Geothermal Energy Collaborative

William Glassley
Elise Brown

Geothermal Overview

- Current state-of-the-art lags behind international efforts due to more favorable investment environment in other states and nations.
- Rebound of technology development is occurring due to improved economic outlooks in California



California remains the national leader in geothermal generation and, with applications currently in process (33 for 1,000 MW), will remain so for years.

Source: GEA

Barriers to Geothermal Development:

- A renewable procurement process that does not recognize ancillary benefits (e.g. voltage support)
- Investment risk for resource characterization
- A renewable procurement process that penalizes baseload renewable technologies
- Inadequate resource characterization (3,100 or 24,000 MW?)
- Initial costs hamper local development
- Perceived as baseload only resource, but can provide flexible capacity

Research needs for geothermal:

Resource Assessment

- Higher resolution geophysical and geochemical methods to characterize and localize resources
- Integrated approaches for resource assessments
- Optimization tools to match diverse resource types with potential applications

Technology

- More efficient use of water (heat transfer and cooling technologies)
- More efficient resource extraction
- Detailed cost, ramp rate, market studies of flexible geothermal (putting the duck on a diet)

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California Solar Energy Collaborative

Pieter Stroeve
Ruxandra Vidu
Jan Kleissl (UCSD)
Masoud Rahman

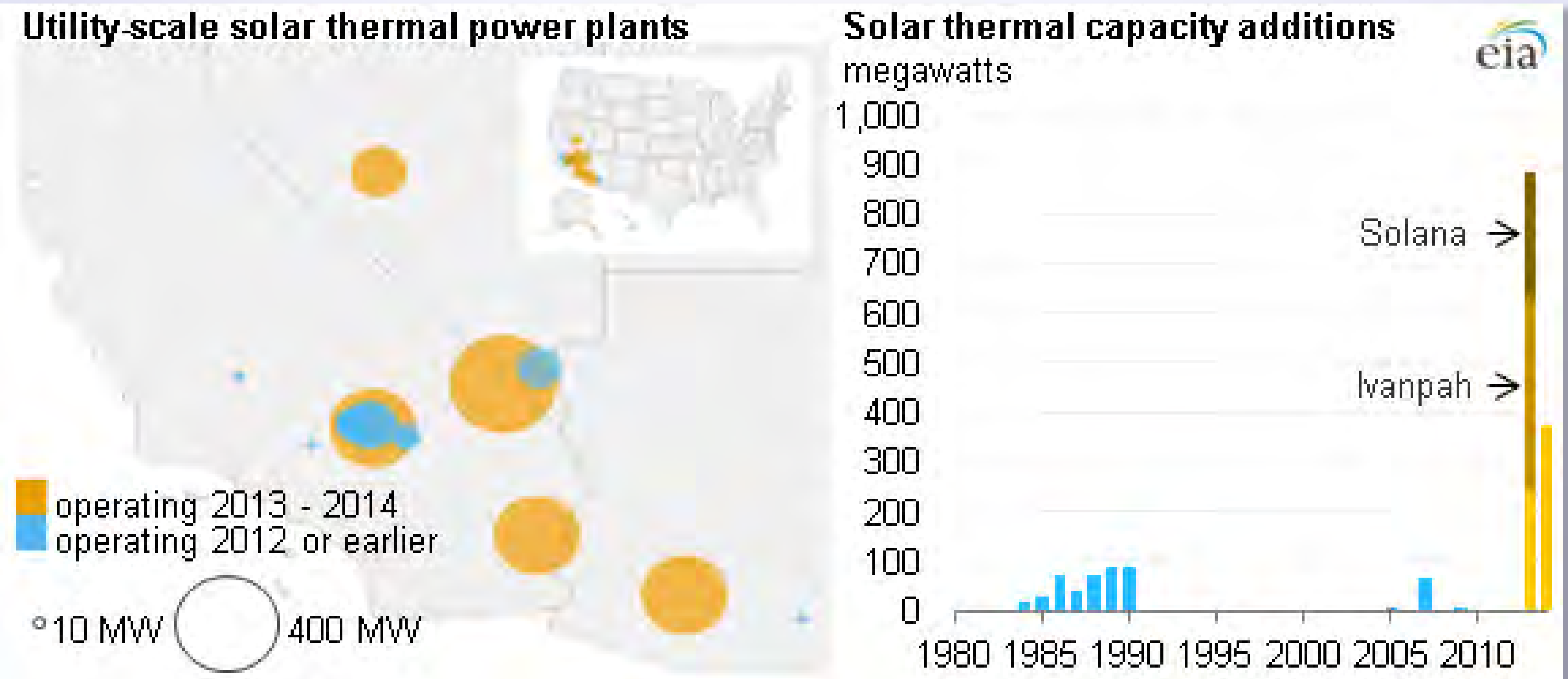
Solar Technologies

- Solar PV
  - Distributed Generation
  - Utility-Scale
- Solar Thermal
- Hybrid Technologies
- Storage
  - Thermal
  - Electrical
  - Gravitational
- Light Harvesting
  - Sun Tracking
  - Light Concentrating

Technology Review: Solar Thermal

Technology	Advantages	Challenges and barriers
CST-Tower **(TRL 07)**	1) Reaching high Temperatures, 2) Storage at high temperatures,	1) Technology is new and not completely mature, 2) It is not modular, 3) Requires high initial investment 4) annual performance, operating cost, initial investment need to be proven in large scale commercial operation 5) Two-axis tracking system is required, 6) Environmental issue of migratory birds 7) Thermal storage requires more research and development on the material storing the heat, storage tank, high temperature corrosion, etc to increase its TRL and decrease its LCOE role.
CST-Trough **(TRL 09)**	1) Technology is mature, 2) Commercially proven annual net plant efficiency of around 14%, 3) Modularity, 4) Best land use factor, 5) Lowest material demand	1) Use of oil-based heat transfer media limits the operating temperature, 2) One-axis tracking is required 3) Plumbing and transfer of HTL to every unit requires energy and results in heat loss, 4) The price of the technology cannot compete with PV
CST-Dish **(TRL 05)**	1) Very high conversion efficiencies –peak solar to net electric conversion over 30%, 2) Modularity	1) annual performance, operating cost, initial investment need to be proven in large scale commercial operation, 2) Low TRL level , 3) no operational unit available, 4) Require 2-axid tracking
CST-Fresnel **(TRL 06)**	1) Less expensive production and installation of Fresnel mirrors	1) require one-axis sun tracking for each mirror 2) Technology for large-scale is not available
CST-Trough hybrid PV-Thermal **(TRL 07)**	1) Concurrent production of electricity and heat	1) The thermal energy from capturing excess heat from PV panels is small compared to other CST technologies and is not suitable for steam generation.
Solar Chimney Power Plant (TRL 06)	1) Simple power generation mechanism	1) High initial investment and capital cost 2) Large land requirement 3) Possible environmental impact which should be studied with more detail

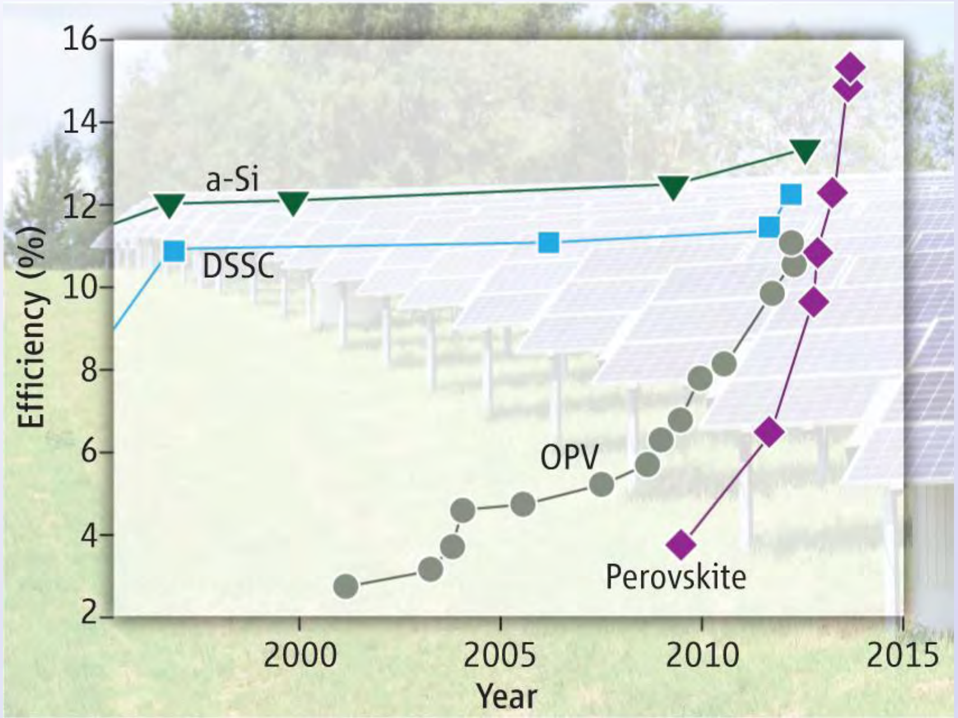
Current Status: Solar Thermal



Source: *erthtechling.com, and U.S. Energy Information Administration, [Annual Electric Generator Report] and Monthly Update (Forms EIA-860 and EIA-860M)*

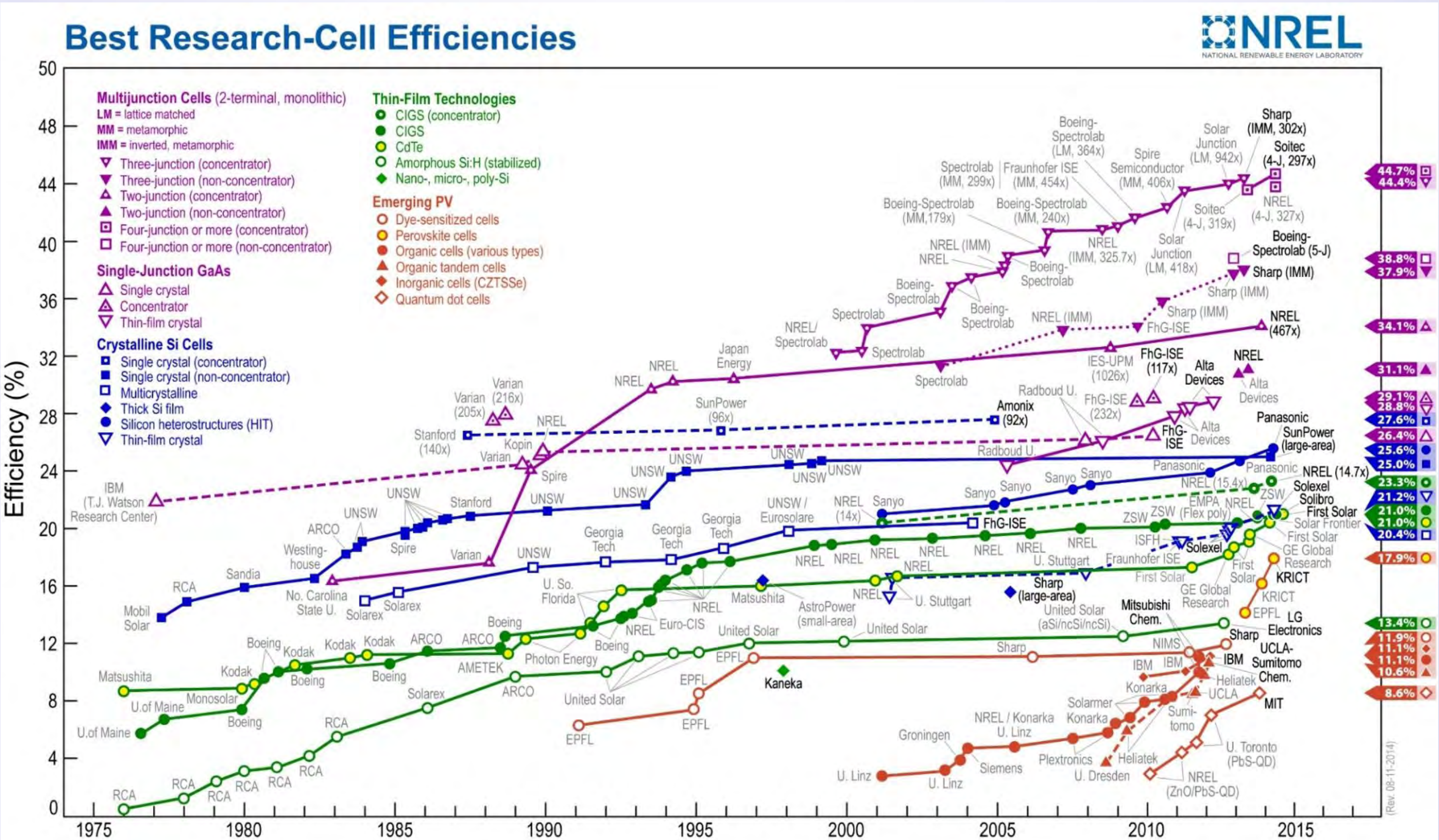
Technology Review: Photovoltaic (PV)

Technology	Technology Readiness Level
Crystalline Silicon	TRL 9
Amorphous Silicon	TRL 9
Thin Film (CdTe, CuInSe, CIGS, GaAs)	TRL 8
Multijunction cells	TRL 8
Organic Solar Cells	TRL 8
Nanostructured Solar Cells (Dye-sensitized, Perovskite, …)	TRL 4



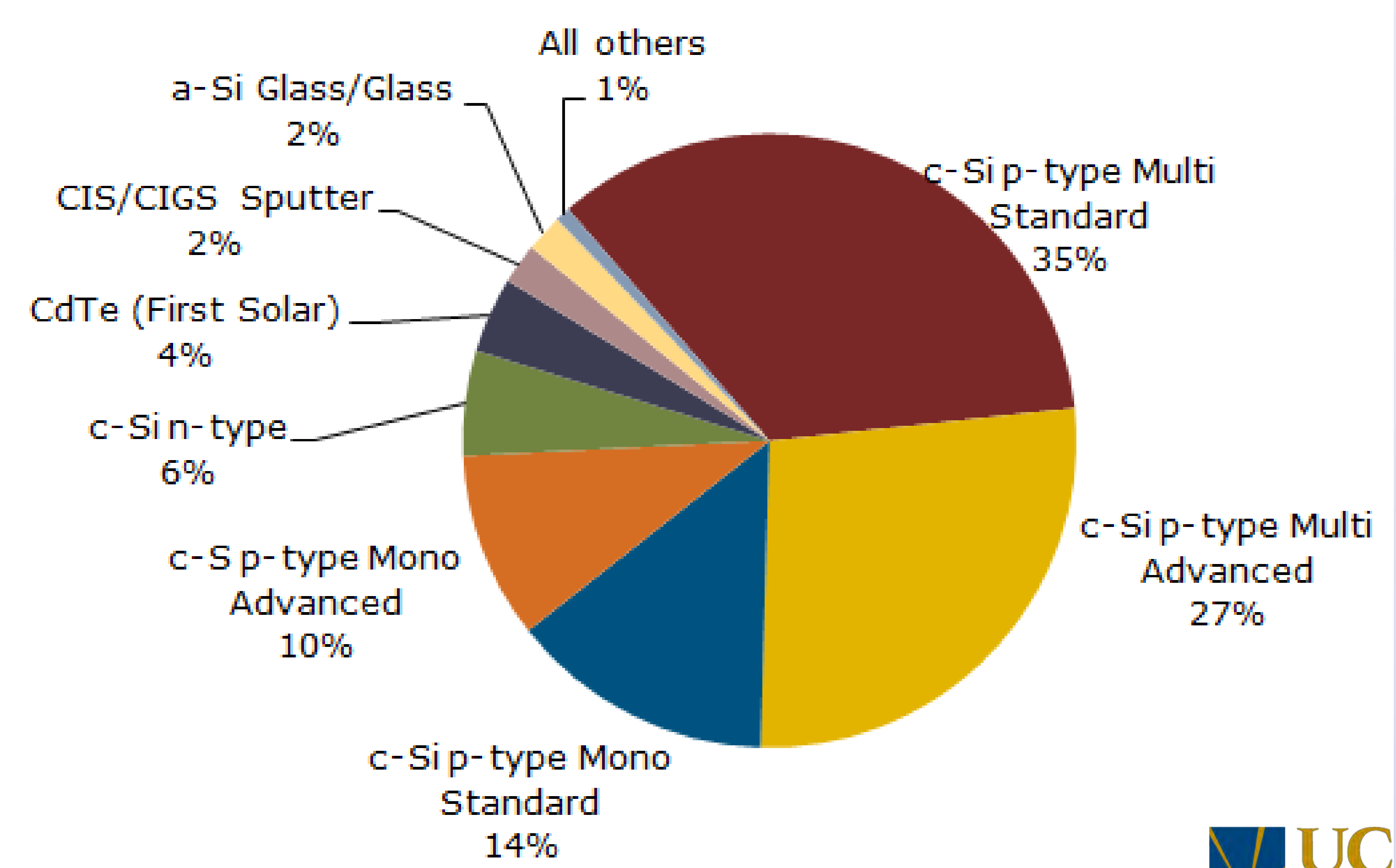
G. Hodes, Science, 2013, Vol. 342, pp. 317-318

Technology Review: Photovoltaic (PV)



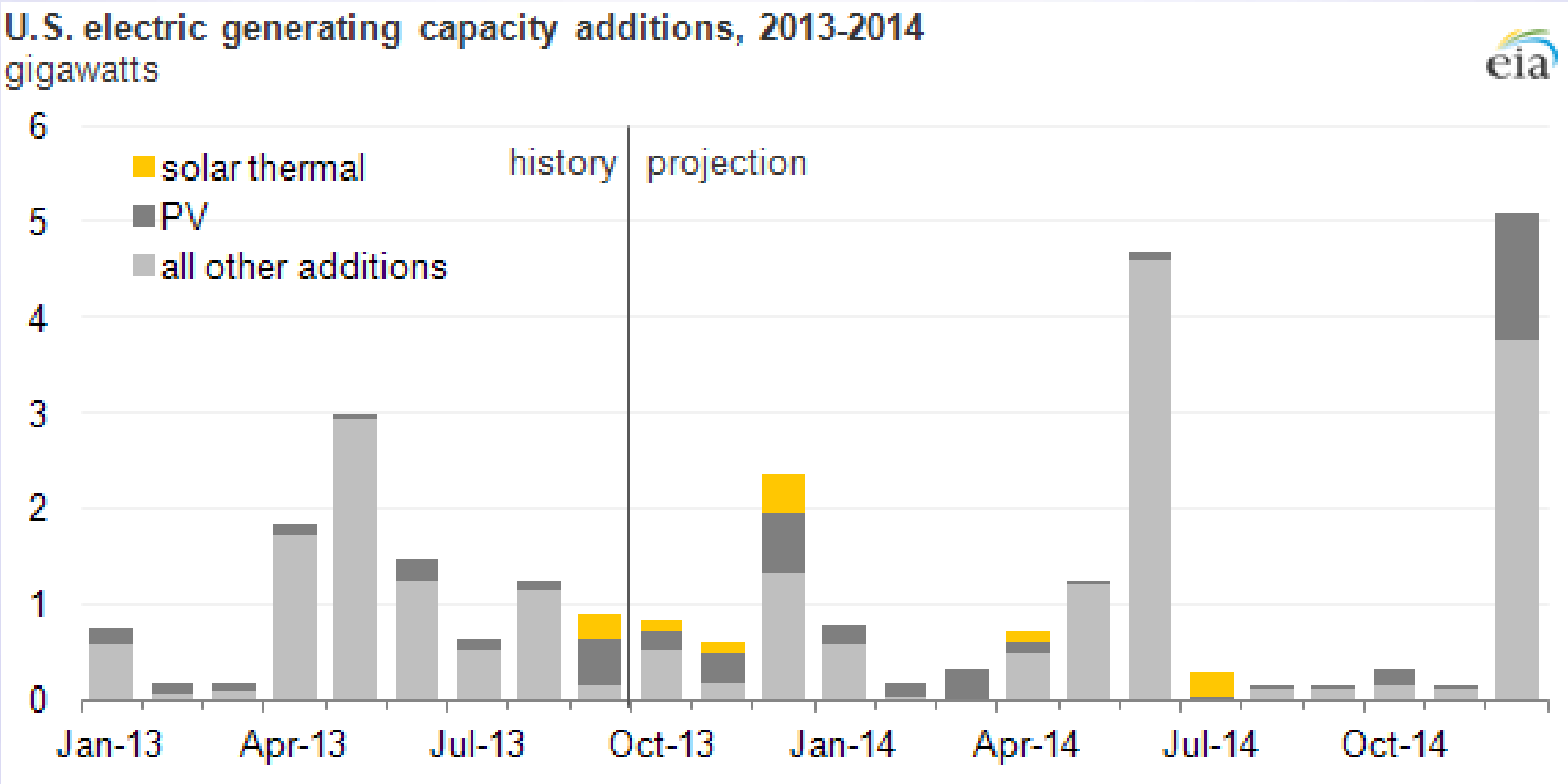
Current Status: Photovoltaic (PV)

2014 Solar PV Module Production by Technology



Source: NPD Solarbuzz *PV Equipment Quarterly*

California Status



Source: *U.S. Energy Information Administration, Annual Electric Generator Report and Monthly Update (Forms EIA-860 and EIA-860M)*

Storage Technologies

Technology	Technology Readiness Level
Thermal Storage	TRL 7
Battery Storage	TRL 9
Gravitational Storage	TRL 7
Solar Fuel (Hydrogen) Storage	TRL 5
Hybrid Solar thermal-Geothermal (Storage through geothermal resource)	TRL 1

Technology	Nameplate Capacity (MW)	Solar Radiation Intensity $kWh/m^2/day$	Storage Capacity (hour)	Capacity Factor	LCOE ($/MWh)
CST-Tower	100	7.6	0	31.5%	152
CST-Tower with Molten Salt Storage	100	7.6	6	49.6%	139
CST-Trough	100	7.6	0	28.0%	172
CST-Trough with Molten Salt Storage	100	7.6	6	41.4%	169
CST-Dish	100	7.6	0	22.3%	230

For the LCOE calculation we used Black and Veatch Company model for Independent Power Producer-Investment Tax Credit scenario

Storage Technologies (cont'd)

TECHNOLOGY	POWER, KW	ENERGY, KWH	INSTALLED CAPITAL COST, $/KW	INSTALLED CAPITAL COST, $/KWH	INTER-CONNECTION COST, $/KW	FIXED O&M, $/KW-YR	VARIABLE O&M, $/KWH
Lithium ion battery	100	400	5,500 – 6,000	1,250 – 1,750	2,000 – 2,500	20 – 25	0.0010 – 0.0015
Lithium ion battery	1,000	4,000	4,250 – 4,750	1,000 – 1,300	1,000 – 1,250	8 – 10	0.0010 – 0.0015
Lithium ion battery	20,000	5,000	1,000 – 1,250	4,500 – 7,000	400 – 600	6 – 8	0.0010 – 0.0015
Vanadium redox flow battery	200	700	5,000 – 5,500	1,400 – 1,600	2,000 – 2,500	15 – 20	0.0015 – 0.0020
Vanadium redox flow battery	1,200	4,000	3,000 – 3,500	900 – 1,100	750 – 1,000	7 – 9	0.0015 – 0.0020
Vanadium redox flow battery	10,000	50,000	3,500 – 4,000	700 - 800	600 – 750	5 – 7	0.0010 – 0.0015

Solar: Future Research and Development

1.) DOE SunShot set the goal of $0.06 per kWh for 2020

2.) CSP-Tower and enhanced thermal storage

3.) Development and production of both Silicon-based and nanostructured solar cells in the US

4.) Soft Costs

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California Biomass Collaborative

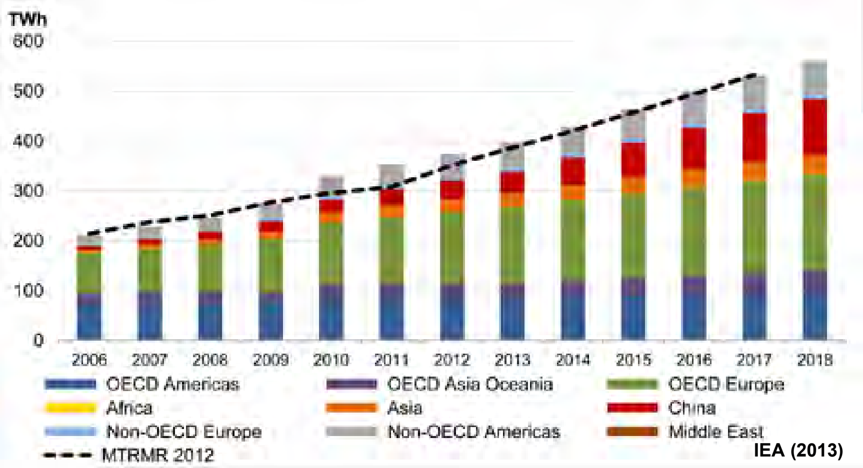
Steve Kaffka
Rob Williams

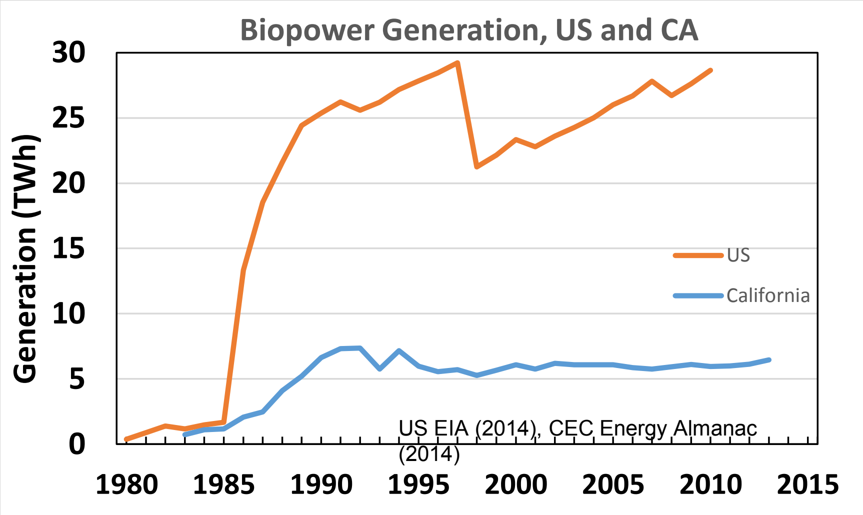
California Renewable Energy Center

State of Bioenergy

(solid fuel and biogas power)

- ~ 400 TWh/y biopower generated in the world
  - Project Increase (IEA, 2013)
- ~ 28 TWh/y biopower US
- 6 TWh/y in California
  - ~ stable for 20 years
  - Some policy in place to encourage new capacity
  - Other policies tend to hinder





Biopower Facilities in California

	Capacity (MW)	Facilities
Solid Fuel (woody& ag.)	574.6	27
LFG Projects	371.3	79
WWTP Facilities	87.8	56
Farm AD	3.8	11
FoodProcess/Urban AD	0.7	2
Totals	1038	175
Solid Fuel (MSW)	63	3

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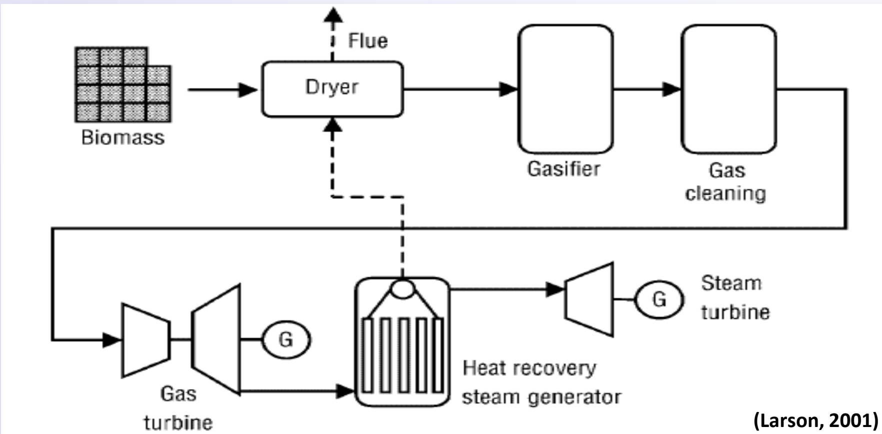
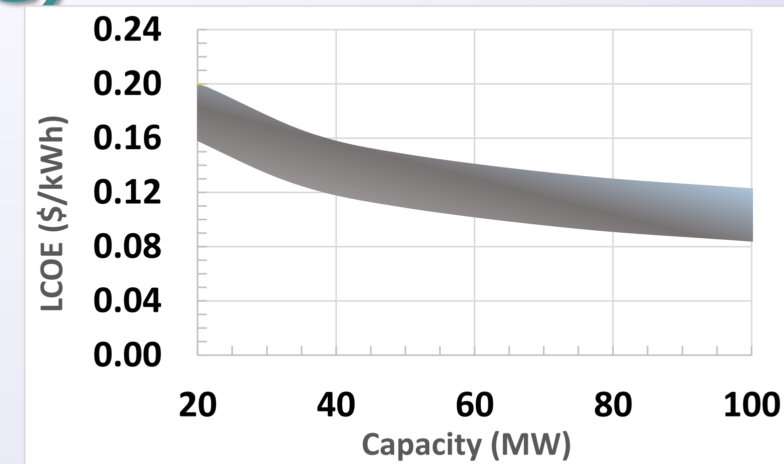
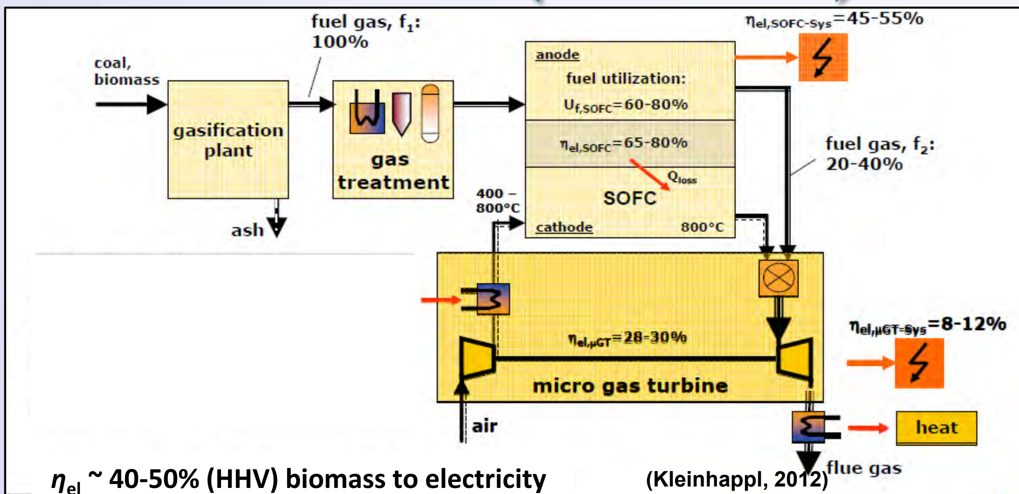
Biomass Integrated-Gasification-Combined-Cycle (BIGCC)



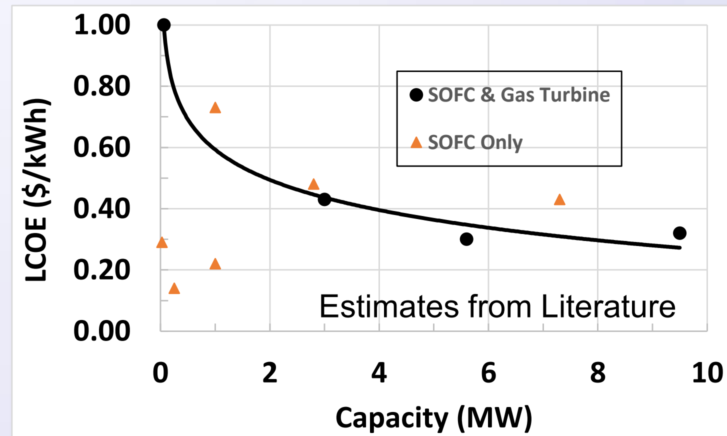


- BIGCC usually means Gas Turbine generator followed by Steam Rankine cycle (as in figure above)
  - Can be: Reciprocating Engine-Generator followed by Steam or Organic Rankine
  - Or Fuel Cell- Gas Turbine combination
- Potential for higher efficiency [30-40%] & improved emissions at large scale (20-100+ MW)
- 6 MW Biomass Pilot Scale Demonstrated in 1990’s
  - A 5.5. MW Recip. Engine – steam turbine CC demonstrated in China ~ 2005
  - Larege Coal IGCC operate in the US
- Cost of electricity projected $0.10 – 0.20/kWh. Competitive w/ new Solid-Fuel Combustion Power

Biomass Integrated-Gasification-Fuel Cell (BIGFC)

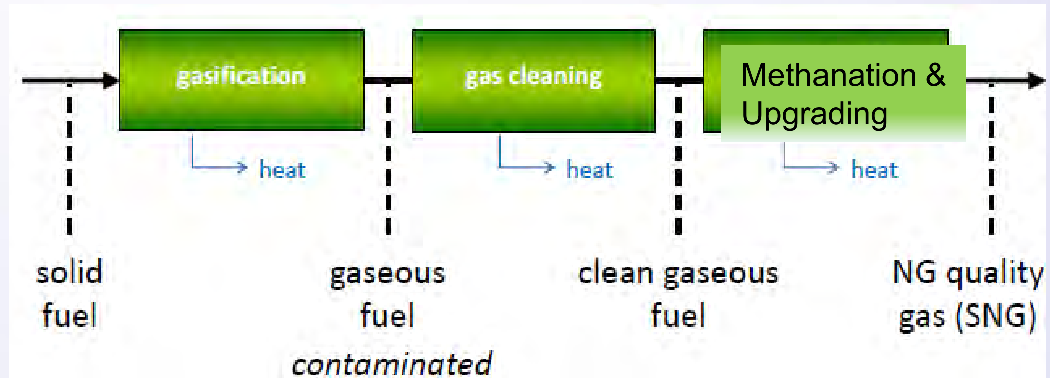


η_{el} ~ 40-50% (HHV) biomass to electricity (Kleinhappl, 2012)

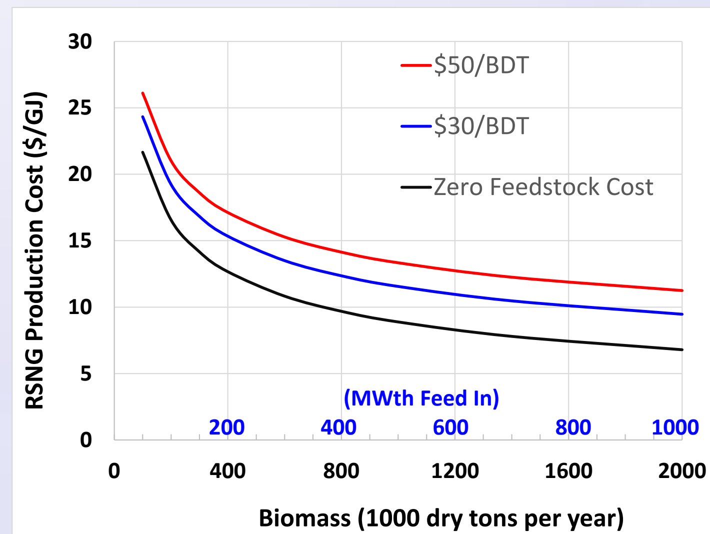


- Can be single cycle or combined cycle (fuel cell-gas turbine (FC_GT) CC shown above)
- Potential for high efficiency & low emissions at small scale: <1 - ~ 10 MW
  - 20-40 % simple cycle (Fuel Cell only)
  - 40-50 % combined cycle (FC-GT)
- Solid Oxide Fuel Cell most promising application
- Lab Scale developmental
- High cost of electricity projected initially

Renewable Synthetic Natural Gas (RSNG)



- Thermal gasification, clean & reform syngas to methane, upgrade to NG quality (remove CO2, H20)
- Thermal Efficiency ~ 65% (to SNG)
- Overall Electric energy eff. ~ 33% (natural gas combined cycle, η= 50%)
- 20MW$_{gas}$ RSNG facility commissioning in Gothenberg Sweden
  - (100 MW$_{gas}$ Phase II in 2016) "GoBiGas"
  - 200 MW$_{gas}$ Plant in design E.ON "Bio2G"



Biomass Research Recommendations

- Costs generally need to be reduced across all biopower technologies
  - Research will help
  - Learning through building capacity of advanced systems will help
- Reliable gas cleaning and tar reforming methods need to be demonstrated - this will improve all biomass gasification applications:
  - Small to Large
  - Power to syngas/fuels production
- For renewable natural gas via thermal gasification, H_2 in final product issue needs to be explored and solved
  - Remove or reduce H_2 and/or
  - Adjust natural gas pipeline specifications to allow higher concentration
- If BIG-FC systems are of interest, develop or expand basic research programs in US and California in this area (almost all literature is from Europe)

Questions & Answers:

Integrated Assessment of Renewable Energy Technology Options

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15 minute break

Program will resume at 10:30 am

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Assessment of Co-located Renewable Generation Potential

One of the goals of these Tasks (2 & 5) was to assess opportunities in which multiple renewable resources could be deployed in a coordinated fashion.

Approach:

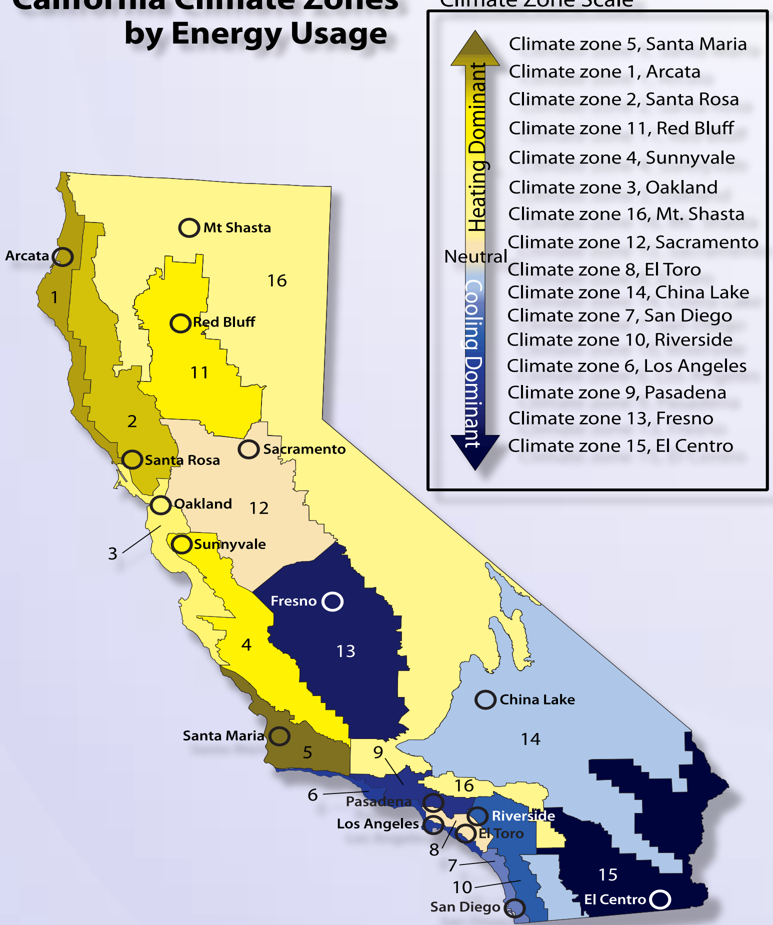
- Identify type examples of sites (Task 2, L.A. Basin) and regions (Task 5) with co-located resources
- Assess resource potential
- Imagine possibilities!

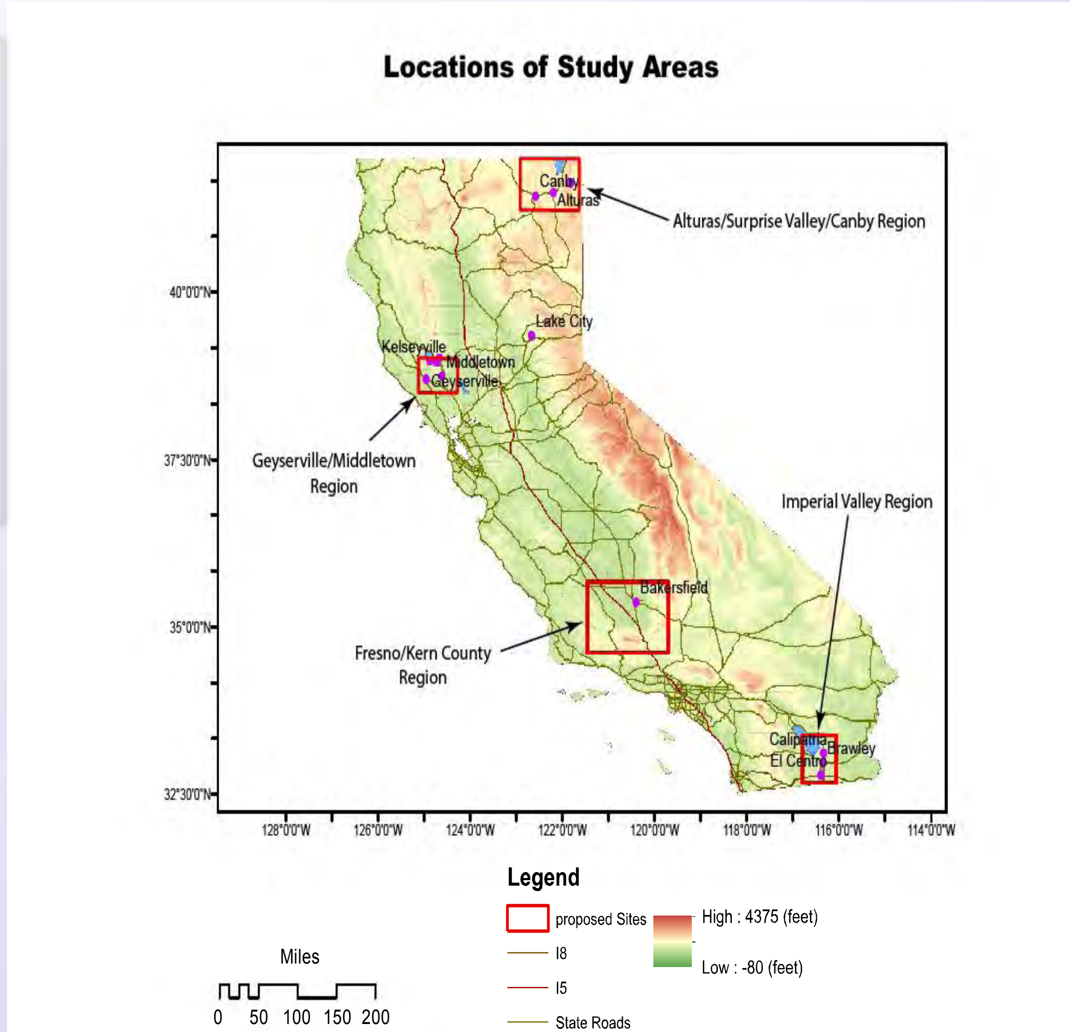
Selected regions:

- Alturas, Geyserville, Kern County Region, Imperial Valley, and Los Angeles Basin

Site Selection *(Task 5)*

California Climate Zones by Energy Usage





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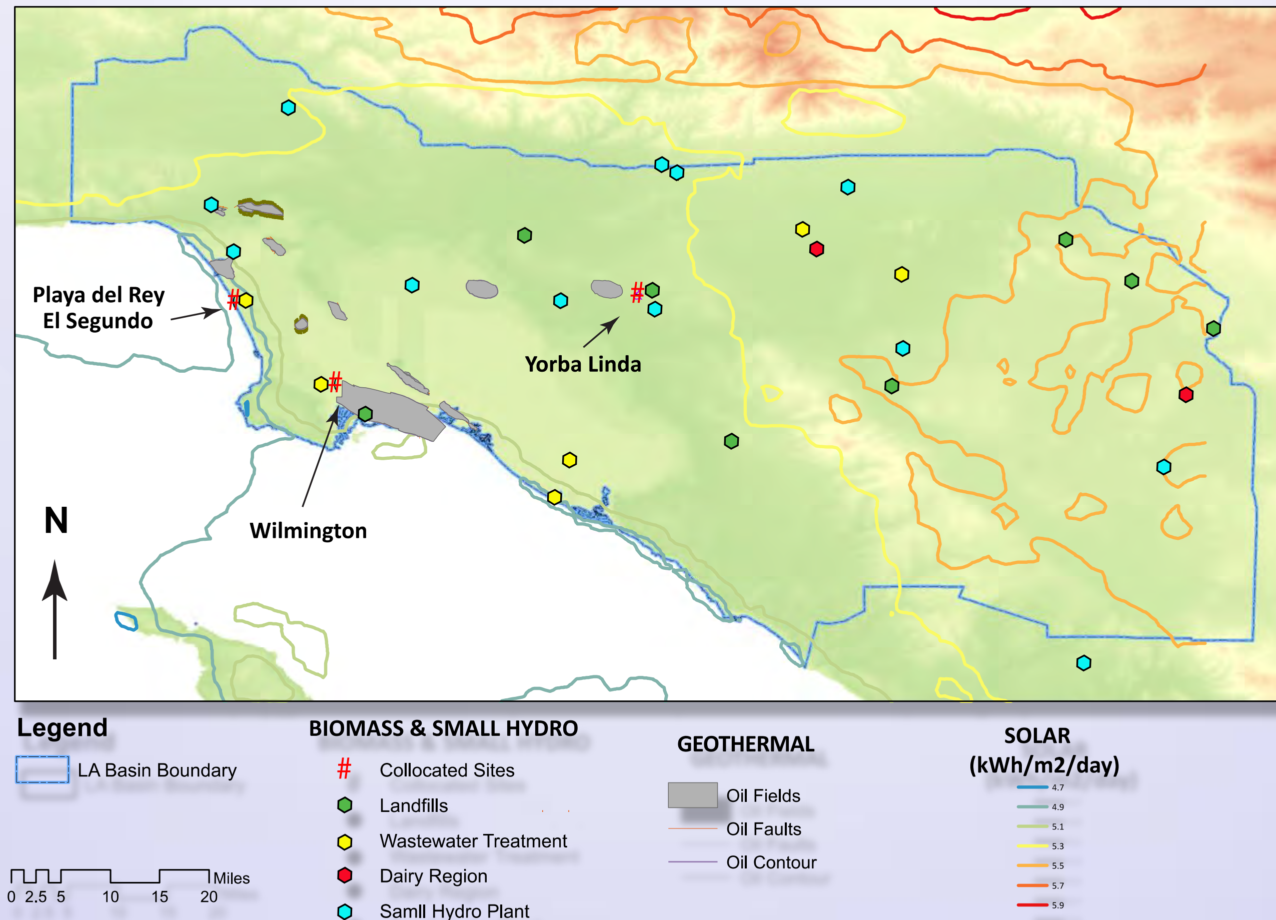
Los Angeles Basin Study Area *(Task 2)*

Locations of Biomass, Small Hydro, Geothermal and Solar Resources



Case study #1:
Alturas

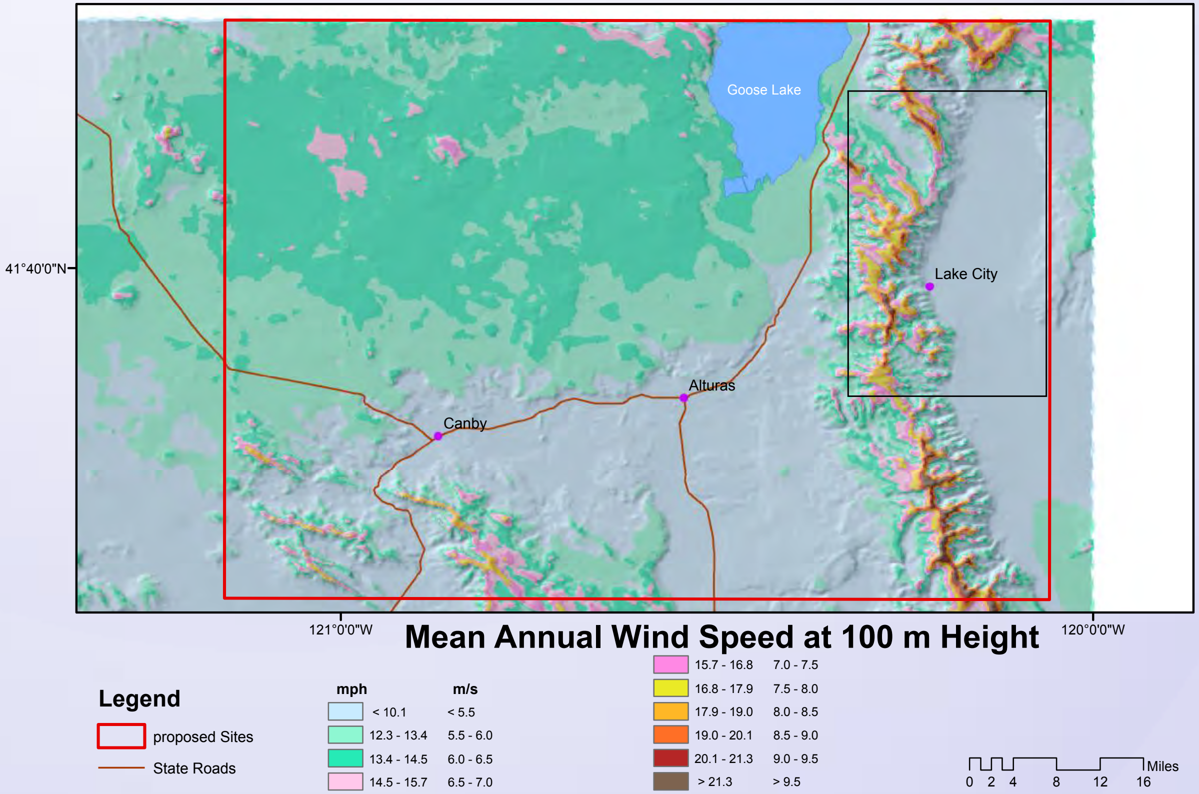
California map: "USA California location map" by Nord NordWest - own work, using United States National Imagery and Mapping Agency data World Data Base II data U.S. Geological Survey (USGS) data. Licensed under Creative Commons Attribution 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:USA_California_location_map.svg#mediaviewer/File:USA_California_location_map.svg
Surprise Valley photo: UC Davis Geothermal Collaborative

Alturas – Resource Assessment

	Potential (MW)
Biomass	44
Geothermal	50
Solar*	140
Wind	1,049

*per 100 sq. miles; CF = 18.4%

Shaded Relief and Wind Resources Map



Technical Biomass Resource and Generation Potential for Modoc County*

	Technical Resource (BDT/y)	Potential Generation (MWe)
Forest Material	324,600	42.8
Agricultural Residue	8,110	1
MSW Biomass	1,400	0.2
Totals	**332,710**	**44**

* From the CBC Resource Update (2014)

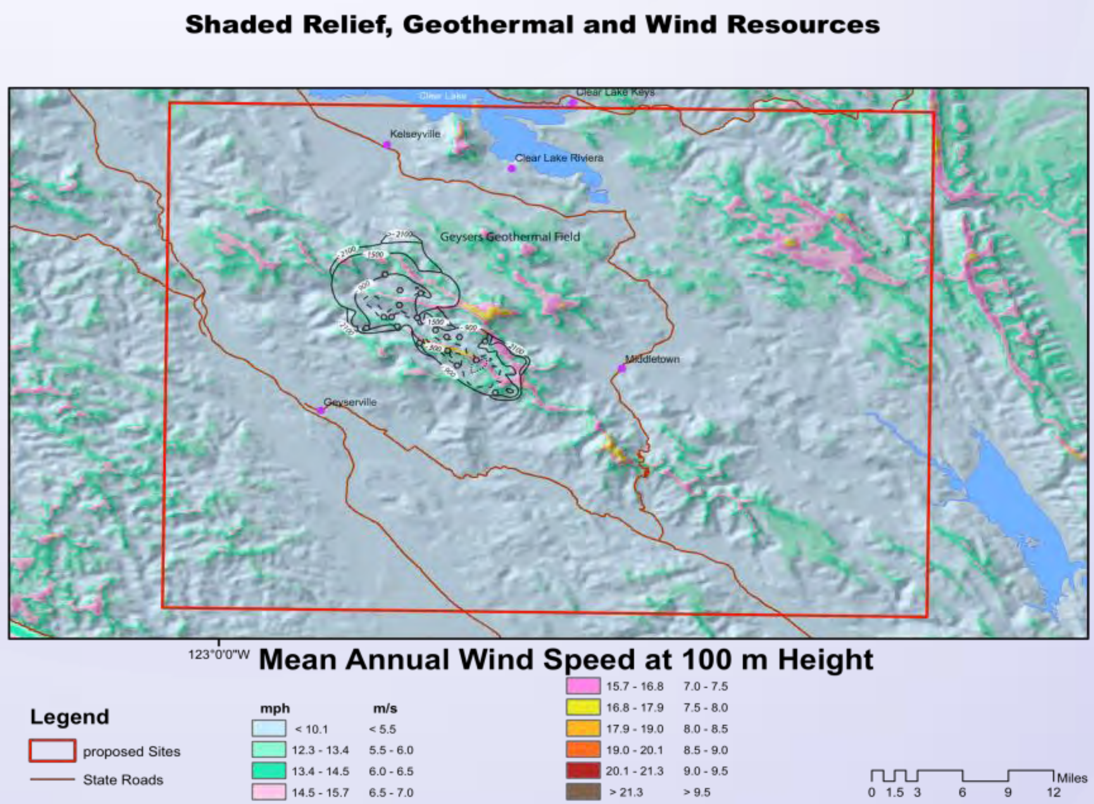
Case study #2:
Geyserville

California map: "USA California location map" by Nord NordWest - own work, using United States National Imagery and Mapping Agency data World Data Base II data U.S. Geological Survey (USGS) data. Licensed under Creative Commons Attribution 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:USA_California_location_map.svg#mediaviewer/File:USA_California_location_map.svg
Geothermal photo: Photo 01049 courtesy of the National Renewable Energy Lab (NREL)
Lake Sonoma: "LakeSonoma2" by CrabTree13 - Own work. Licensed under Creative Commons Attribution-Share Alike 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:LakeSonoma2.jpg#mediaviewer/File:LakeSonoma2.jpg

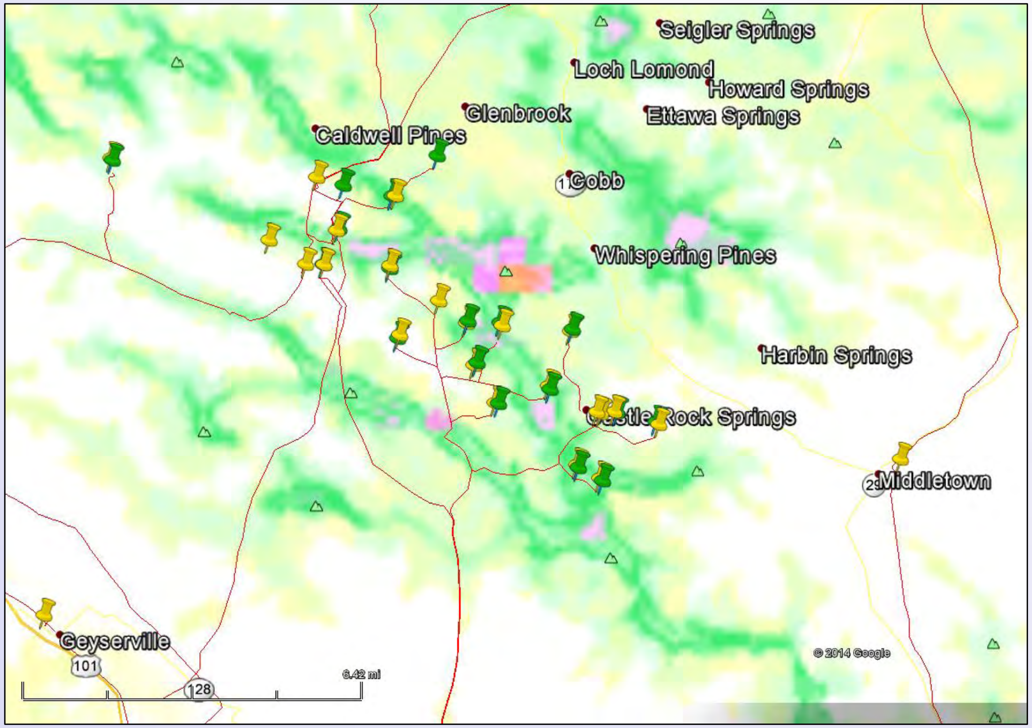
Geyserville – Resource Assessment

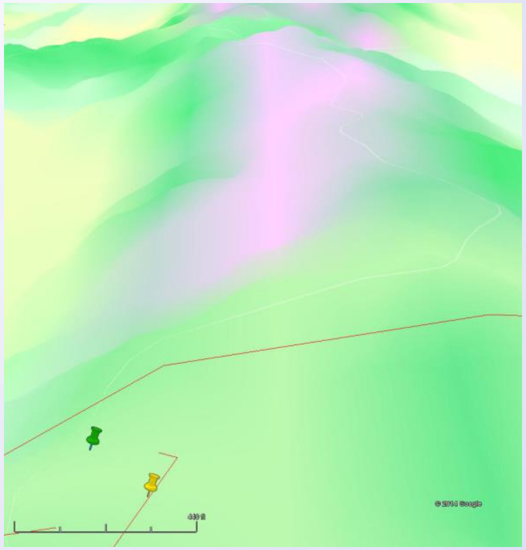
	MW
Biomass	101
Geothermal	1,610
Solar*	140
Wind	30

* per 100 sq. miles; CF = 18.9%
** Focused on Geysers geothermal fields



Wind: Development Potential – Geyserville





- Potential to collocate wind with existing Geysers geothermal plants
- Existing infrastructure: geothermal plants, roads, work/staging areas coincide with windiest areas
- Conservatively, 13 turbines, 29.9 MW in 7.0-7.6 m/s wind

Case study #3:
Kern – San Joaquin Valley

San Joaquin Valley: "California's Central Valley" by Amadscientist - Own work. Licensed under Creative Commons Zero, Public Domain Dedication via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:California%27s_Central_Valley.JPG#mediaviewer/File:California%27s_Central_Valley.JPG

Map of California: "USA California location map" by NordNordWest - own work, usingUnited States National Imagery and Mapping Agency dataWorld Data Base II dataU.S. Geological Survey (USGS) data. Licensed under Creative Commons Attribution 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:USA_California_location_map.svg#mediaviewer/File:USA_California_location_map.svg

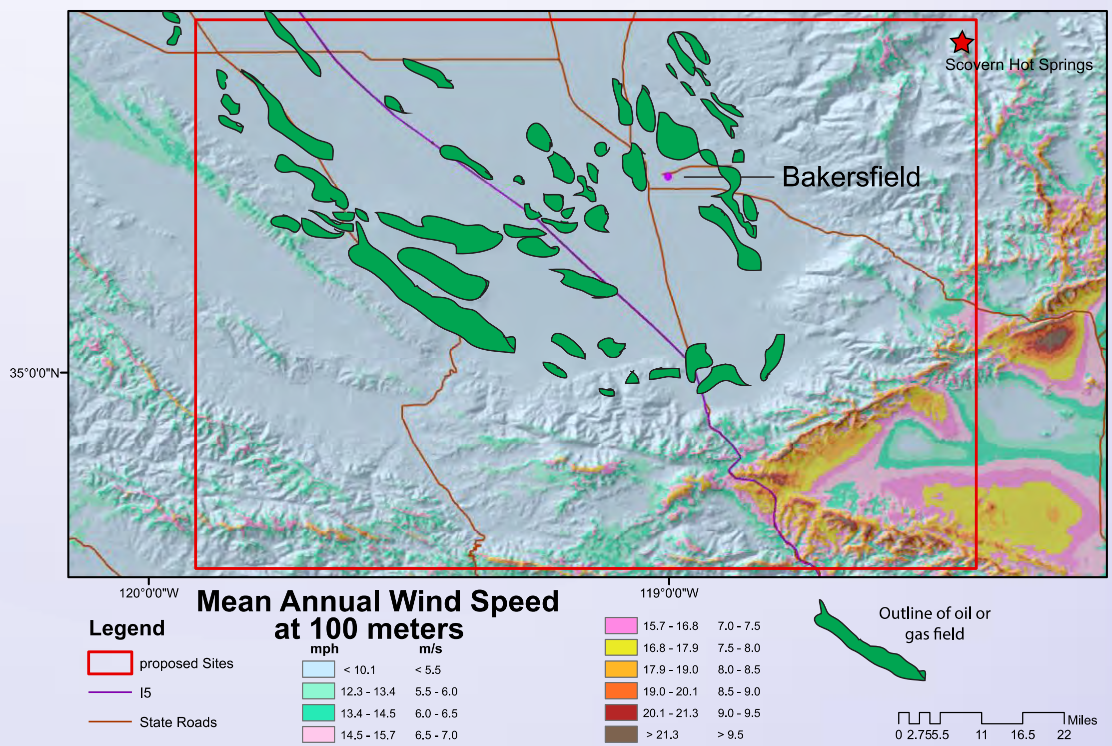
Oil wells: "MidwaySunsetWells" by User:Antandrus. Original uploader was Antandrus at en.wikipedia - Transferred from en.wikipedia(Original text : User:Antandrus). Licensed under Creative Commons Attribution-Share Alike 3.0 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:MidwaySunsetWells.jpg#mediaviewer/File:MidwaySunsetWells.jpg

Kern – Resource Assessment

	MW
Biomass	119
Geothermal	10-100
Solar*	140
Wind	0**

* per 100 sq. miles; CF = 19.5%
** for San Joaquin Valley; potential is very, very high in Tehachapi Pass, Mojave Desert

Locations of Oil & Gas Fields and Wind Resources



Case study #4:
Imperial

Irrigated fields: "Imperial valley fields" by Spacenut525 at English Wikipedia - Own workTransferred from en.wikipedia to Commons by MathewTownsend.. Licensed under Public domain via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Imperial_valley_fields.jpg#mediaviewer/File:Imperial_valley_fields.jpg

California Map: See citation on previous slides.

Salton Sea: "Salton Sea from Space". Licensed under Public domain via Wikimedia Commons http://commons.wikimedia.org/wiki/File:Salton_Sea_from_Space.jpg#mediaviewer/File:Salton_Sea_from_Space.jpg

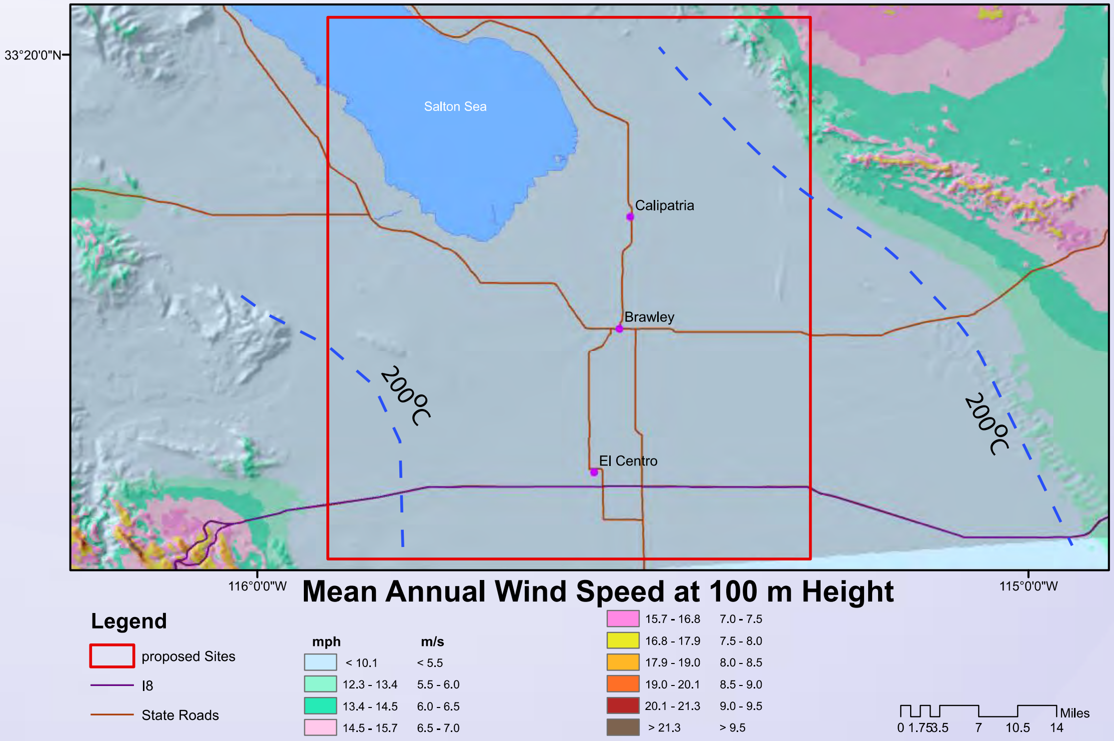
Desert Vista: "Vista of Anza Borrego". Licensed under Creative Commons Attribution-Share Alike 2.5 via Wikimedia Commons - http://commons.wikimedia.org/wiki/File:Vista_of_Anza_Borrego.jpg#mediaviewer/File:Vista_of_Anza_Borrego.jpg

Imperial – Resource Assessment

	MW
Biomass	20
Geothermal	2,900
Solar*	140
Wind	1,051

* per 100 sq. miles; CF= 21.3%

Geothermal and Wind Resources



Summary Table: Energy Potential by Region

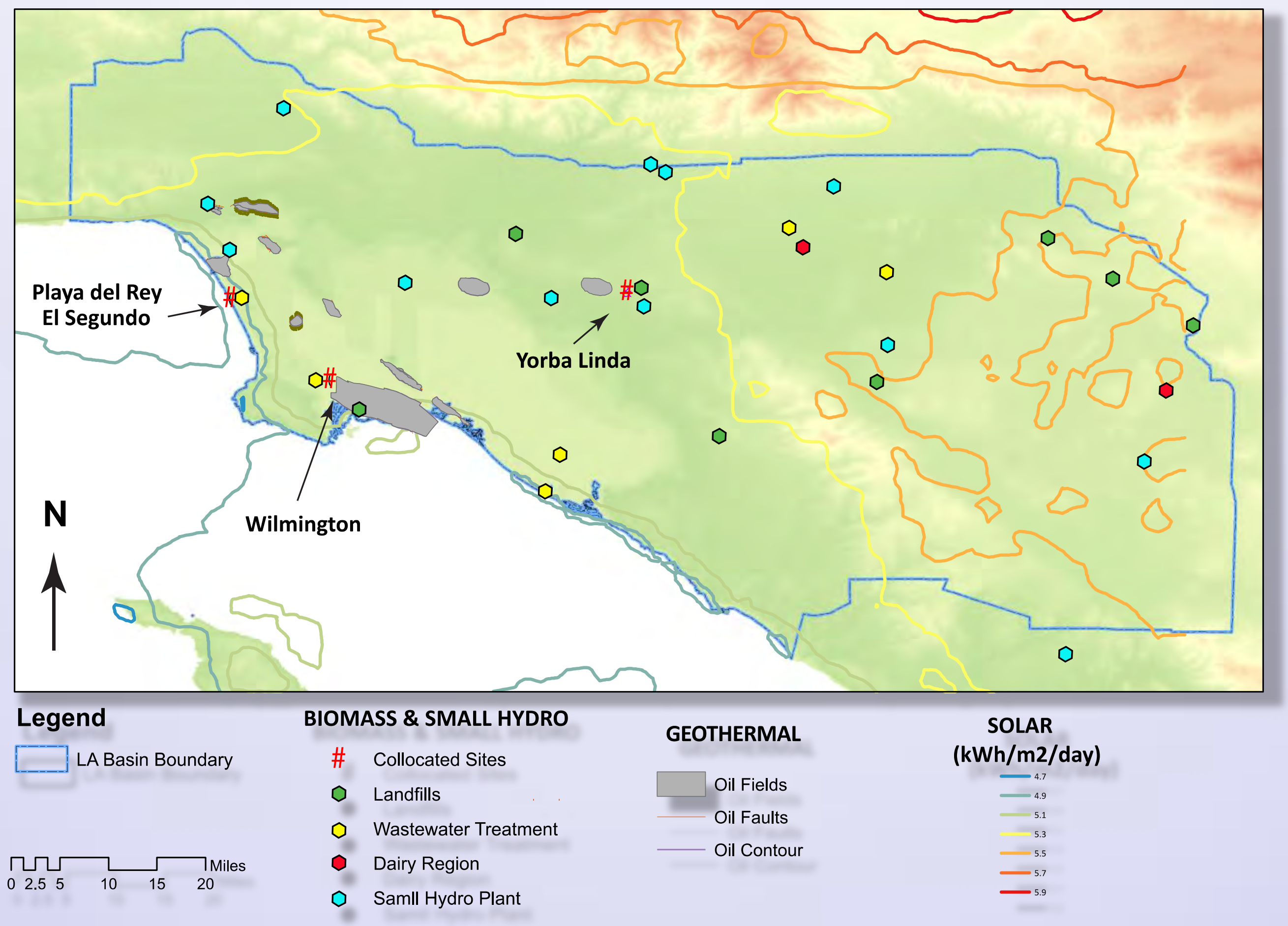
	Biomass (MWe)	Geothermal (MWe)	Solar (PV) (kWh/m^2/day)	Wind (MWe)
Alturas	44	50	5.0 - 5.5	1,049
Geyserville	101	1,610	5.0 – 5.5	30
Kern	119	10-100	5.7	0*
Imperial	20	2,900	6.6	1,051

Observations:

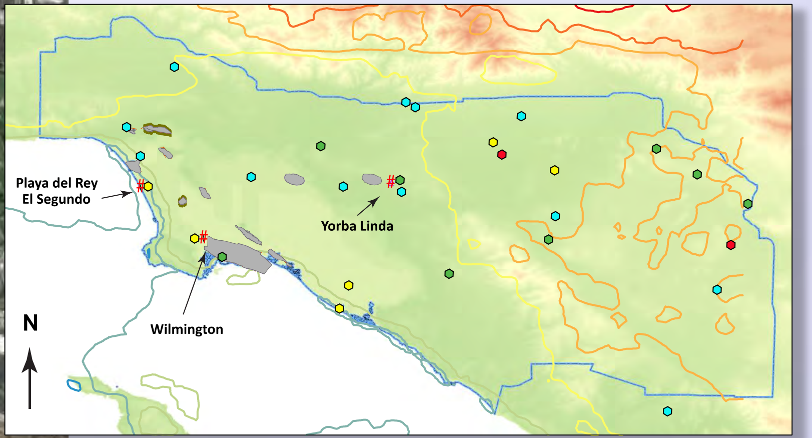
- **In all cases, coordinate generation is possible, but base resources differ**
- **Overall capacity in these limited areas would double current renewable generation capacity**

Los Angeles Basin Study Area *(Task 2)*

Locations of Biomass, Small Hydro, Geothermal and Solar Resources

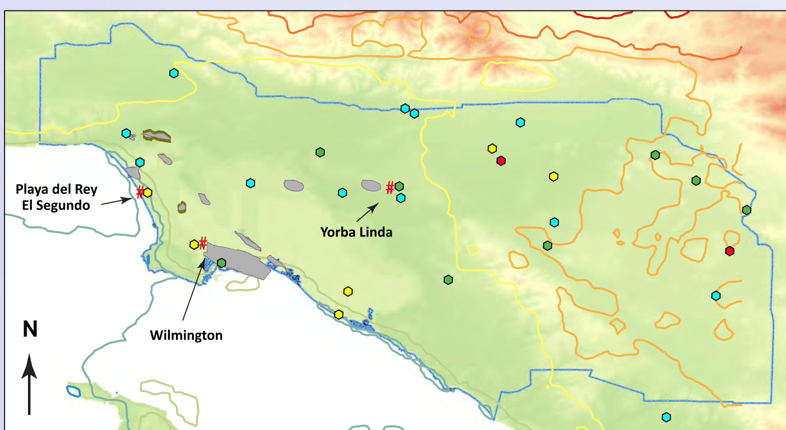


Playa del Rey



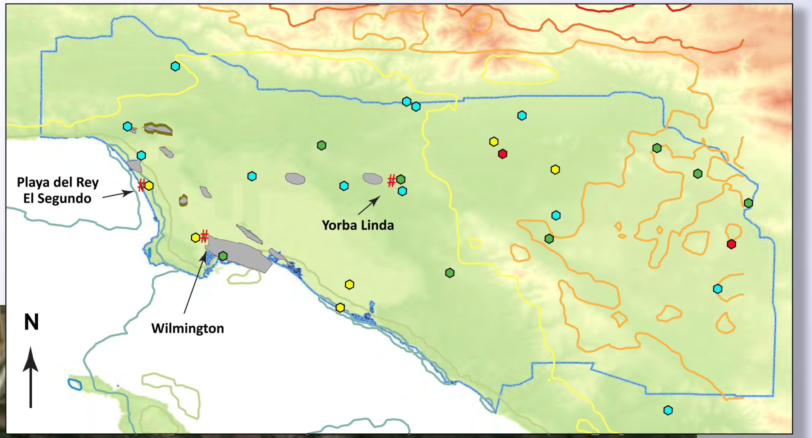
Source: Google

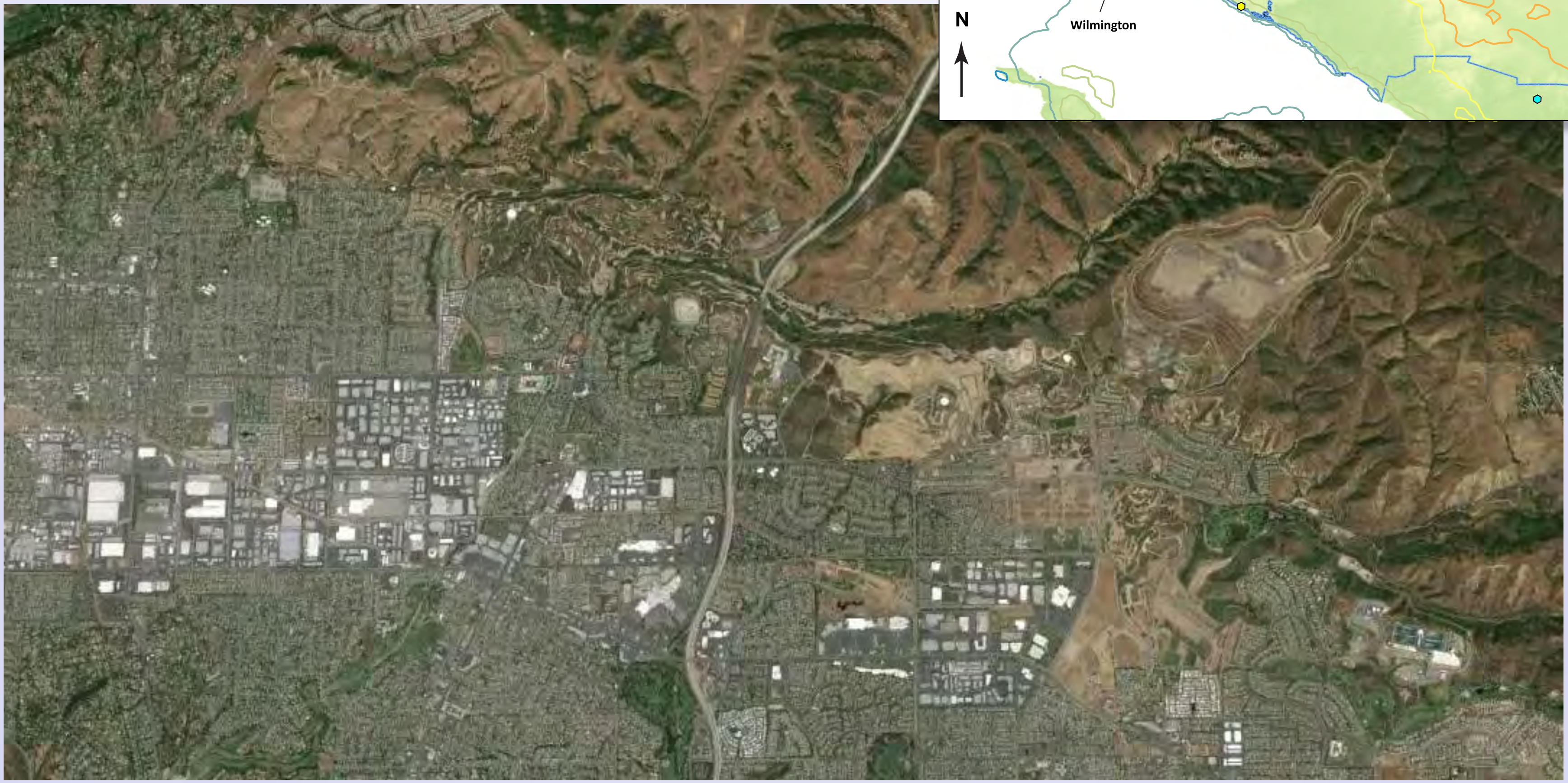
Wilmington



Source: Google

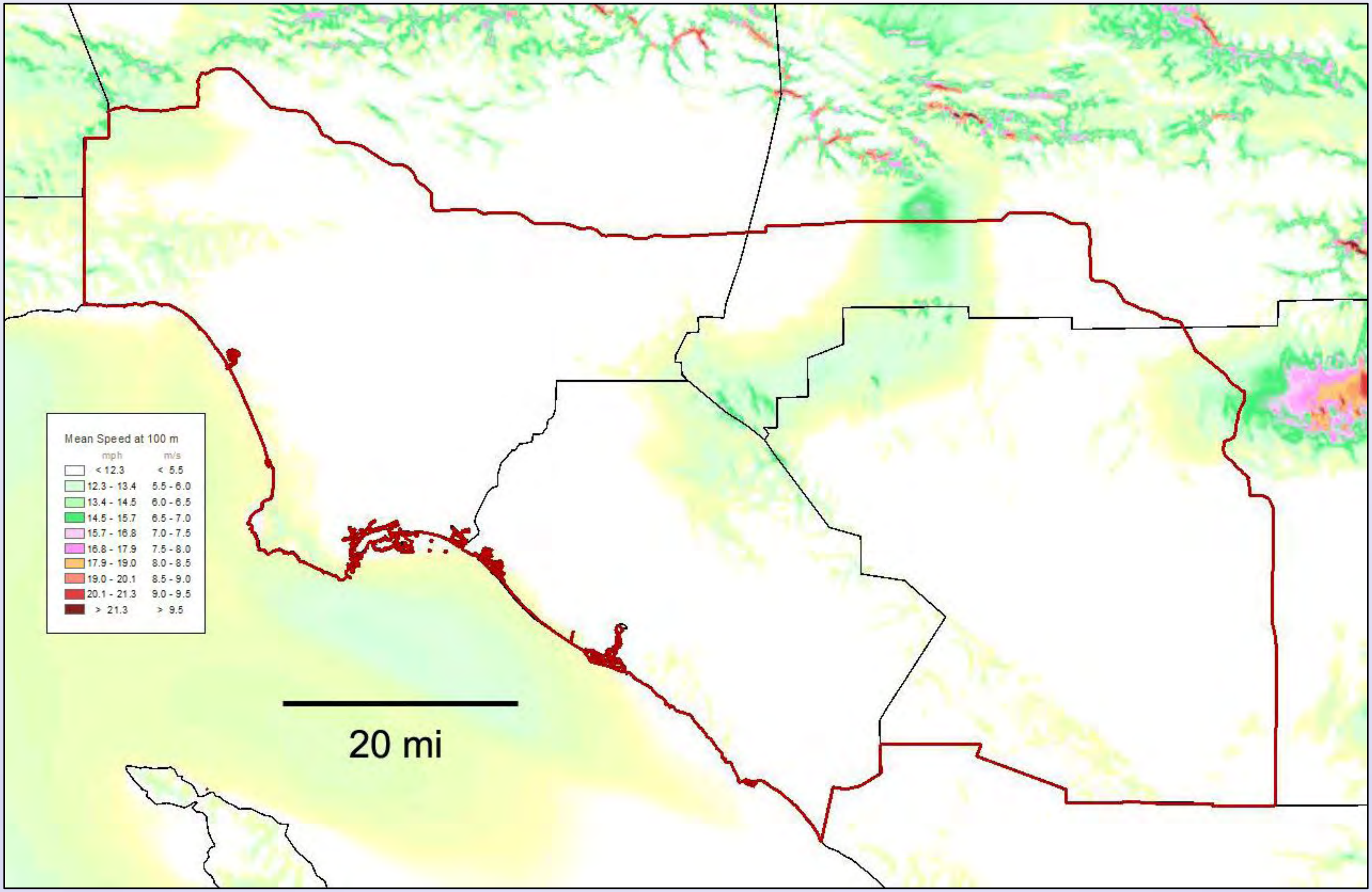
Yorba Linda



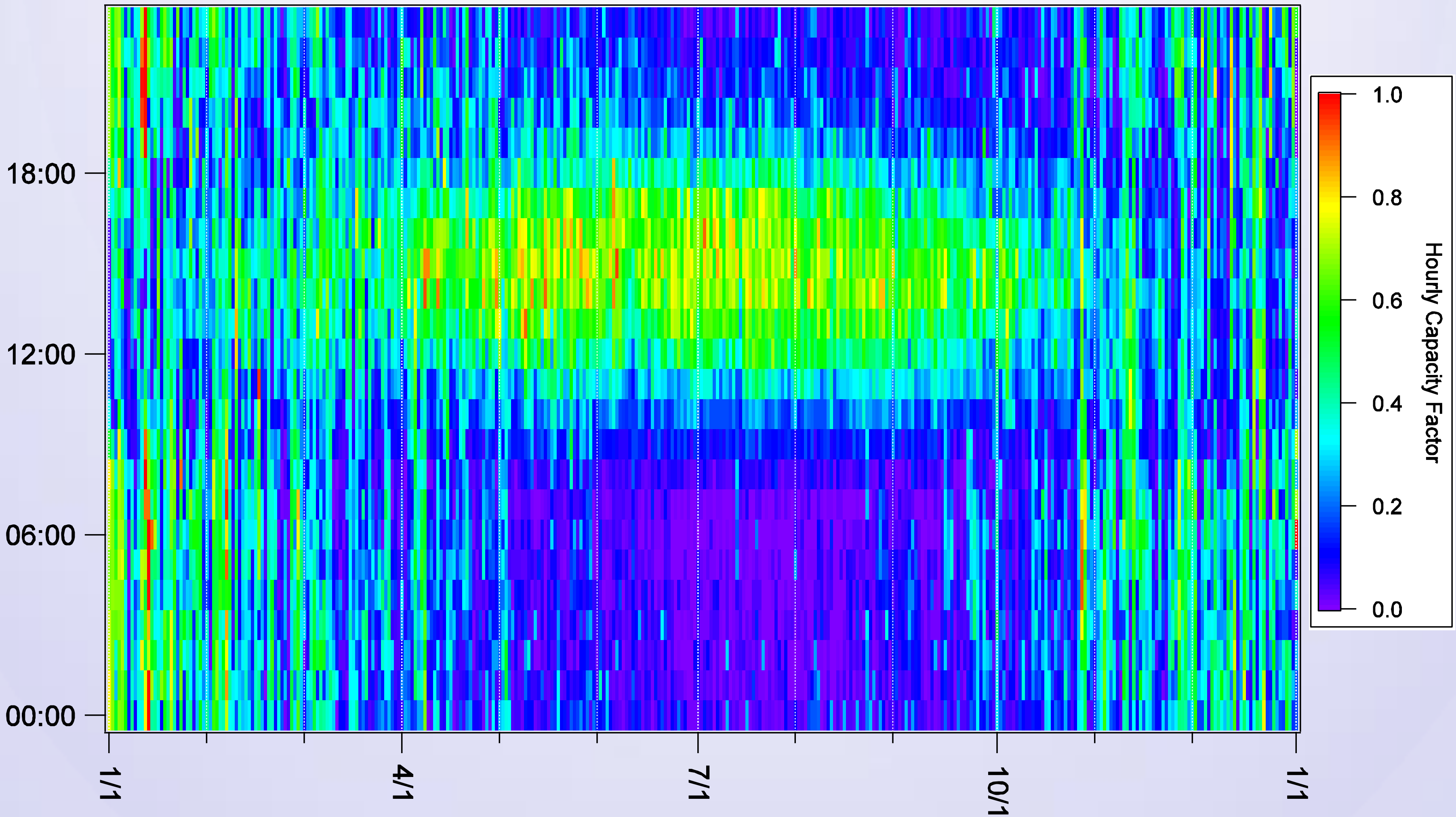


Source: Google

Wind: Development Potential – LA Basin



Wind Power Production at Olinda Alpha Landfill



Capacity Factor: 28%

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Solar Technical Potential in the LA Basin

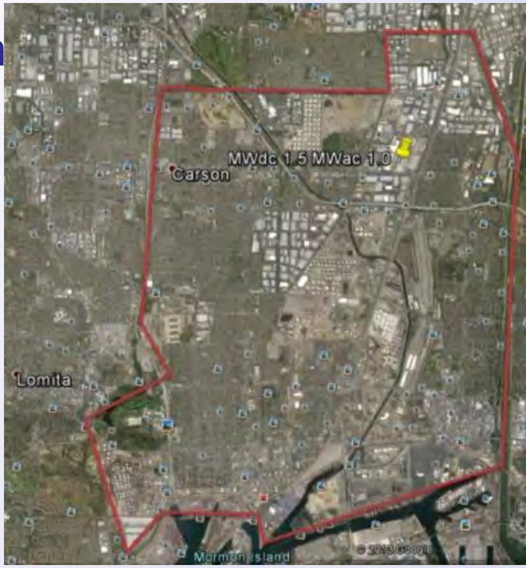
- Estimated Solar Potential (12 months x 24 hours)
  - Warehouse rooftop
  - Vacant land
- PV performance model
  - SolarAnywhere resource data
  - 20° tilt, 60% roof availability, power density: 122 W m²

0	0	0	0	0	0.0	0.0	0.4	2.9	5.1	6.4	6.7	6.5	6.6	5.3	4.0	1.6	0.0	0.0	0	0	0	0	0
0	0	0	0	0	0.0	0.0	0.9	3.6	6.0	7.4	8.0	8.0	7.3	6.8	5.1	2.6	0.4	0.0	0	0	0	0	0
0	0	0	0	0	0.0	0.2	2.0	4.2	5.9	7.9	8.5	8.5	6.9	7.6	5.4	3.4	1.0	0.0	0	0	0	0	0
0	0	0	0	0	0.0	1.0	3.3	5.5	7.5	8.9	9.7	10.0	9.4	8.6	6.4	4.3	1.7	0.2	0	0	0	0	0
0	0	0	0	0	0.2	1.4	3.5	5.9	7.9	9.1	9.7	9.9	9.4	8.4	6.6	4.4	2.0	0.4	0	0	0	0	0
0	0	0	0	0	0.2	1.0	2.4	4.2	6.2	7.7	8.5	8.7	8.8	7.9	6.1	4.3	2.2	0.7	0	0	0	0	0
0	0	0	0	0	0.1	1.0	2.5	4.5	6.5	8.6	9.1	9.6	9.2	8.3	6.5	4.5	2.4	0.7	0	0	0	0	0
0	0	0	0	0	0.0	0.7	2.3	4.2	6.4	8.4	9.3	9.0	8.6	8.0	6.1	4.0	1.8	0.3	0	0	0	0	0
0	0	0	0	0	0.0	0.4	1.8	3.5	5.6	7.6	8.3	7.9	7.5	6.8	4.6	2.9	0.8	0.0	0	0	0	0	0
0	0	0	0	0	0.0	0.2	2.2	4.3	5.7	6.7	7.1	7.0	6.4	5.8	3.9	1.8	0.1	0.0	0	0	0	0	0
0	0	0	0	0	0.0	0.0	1.2	3.7	5.5	6.3	7.1	7.0	6.4	5.3	3.2	0.8	0.0	0.0	0	0	0	0	0
0	0	0	0	0	0.0	0.0	0.6	3.4	5.6	6.9	7.6	7.5	6.5	5.4	3.6	0.8	0.0	0.0	0	0	0	0	0

Areas surveyed

- Proximity to geothermal sources:

Wilmington



El Segundo

Yorba Linda

Technical Solar Generation Potential

- Installed Capacity
  - El Segundo: 10.1 MW
  - Wilmington: 334 MW
  - Yorba Linda: 603 MW

- Similar solar resource
- Winter low:
  4.5 MWh / MW / day
- Summer high:
  7.8 MWh / MW / day

hour of day →

MWh

Month of year ↑

El Segundo

0	0	0	0	0	0.0	0.0	0.4	2.9	5.1	6.4	6.7	6.5	6.6	5.3	4.0	1.6	0.0	0	0	0	0	0	0
0	0	0	0	0	0.0	0.0	0.9	3.6	6.0	7.4	8.0	8.0	7.3	6.8	5.1	2.6	0.4	0	0	0	0	0	0
0	0	0	0	0	0.0	0.2	2.0	4.2	5.9	7.9	8.5	8.5	6.9	7.6	5.4	3.4	1.0	0.0	0	0	0	0	0
0	0	0	0	0	0.0	1.0	3.3	5.5	7.5	8.9	9.7	10.0	9.4	8.6	6.4	4.3	1.7	0.2	0	0	0	0	0
0	0	0	0	0	0.2	1.4	3.5	5.9	7.9	9.1	9.7	9.9	9.4	8.4	6.6	4.4	2.0	0.4	0	0	0	0	0
0	0	0	0	0	0.2	1.0	2.4	4.2	6.2	7.7	8.5	8.7	8.8	7.9	6.1	4.3	2.2	0.7	0	0	0	0	0
0	0	0	0	0	0.1	1.0	2.5	4.5	6.5	8.6	9.1	9.6	9.2	8.3	6.5	4.5	2.4	0.7	0	0	0	0	0
0	0	0	0	0	0.0	0.7	2.3	4.2	6.4	8.4	9.3	9.0	8.6	8.0	6.1	4.0	1.8	0.3	0	0	0	0	0
0	0	0	0	0	0.0	0.4	1.8	3.5	5.6	7.6	8.3	7.9	7.5	6.8	4.6	2.9	0.8	0.0	0	0	0	0	0
0	0	0	0	0	0.0	0.2	2.2	4.3	5.7	6.7	7.1	7.0	6.4	5.8	3.9	1.8	0.1	0.0	0	0	0	0	0
0	0	0	0	0	0.0	0.0	1.2	3.7	5.5	6.3	7.1	7.0	6.4	5.3	3.2	0.8	0.0	0.0	0	0	0	0	0
0	0	0	0	0	0.0	0.0	0.6	3.4	5.6	6.9	7.6	7.5	6.5	5.4	3.6	0.8	0.0	0.0	0	0	0	0	0

Wilmington

0	0	0	0	0	0	0	12	87	163	208	231	230	224	188	137	56	1	0	0	0	0	0	0
0	0	0	0	0	0	0	28	112	184	237	255	264	255	218	159	88	13	0	0	0	0	0	0
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0	0	0	0	0	1	22	71	138	223	287	320	321	300	269	214	144	66	10	0	0	0	0	0
0	0	0	0	0	0	15	64	127	196	241	275	290	271	242	181	110	30	0	0	0	0	0	0
0	0	0	0	0	0	7	67	137	195	240	266	274	250	217	152	68	4	0	0	0	0	0	0
0	0	0	0	0	0	0	39	107	167	205	224	230	212	161	104	28	0	0	0	0	0	0	0
0	0	0	0	0	0	0	20	108	181	227	248	245	219	178	117	27	0	0	0	0	0	0	0

Yorba Linda

0	0	0	0	0	0	0	23	176	301	396	456	462	425	375	269	116	2	0	0	0	0	0	0
0	0	0	0	0	0	0	55	238	381	471	537	527	499	425	311	183	29	0	0	0	0	0	0
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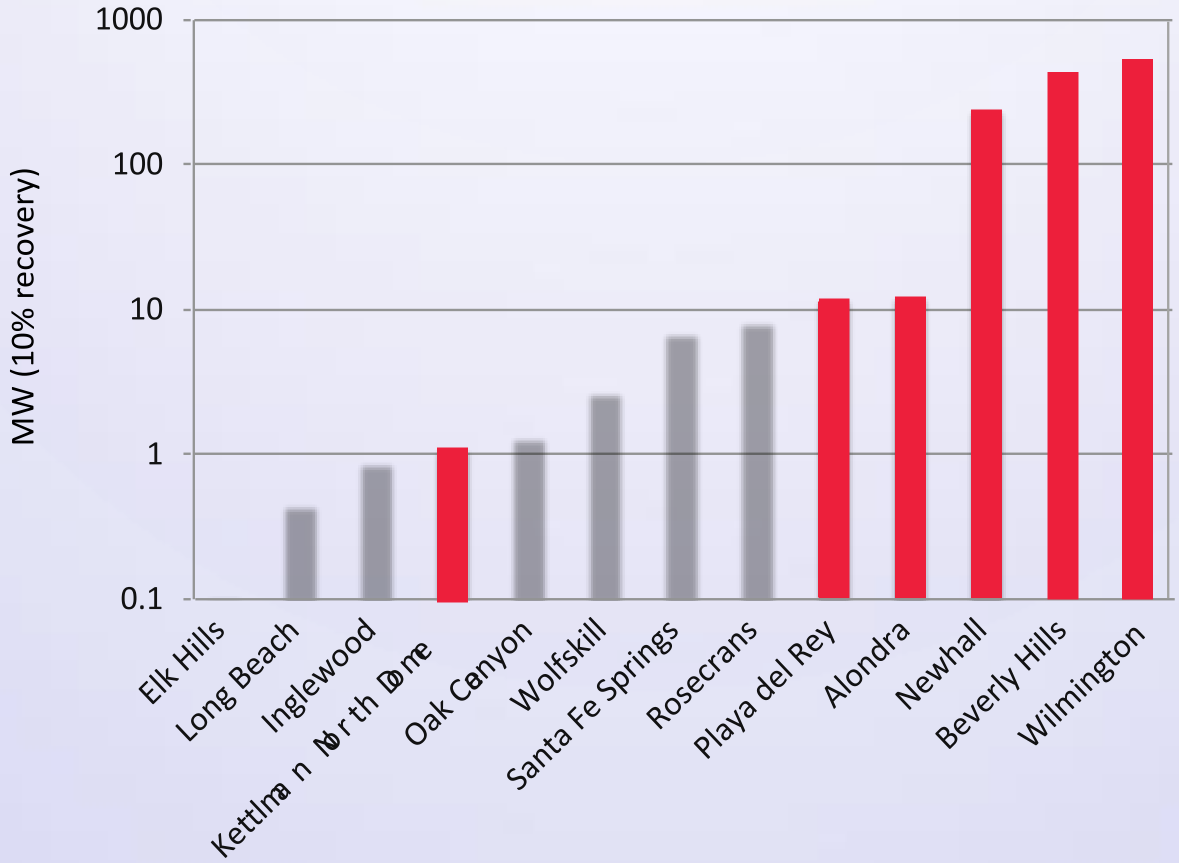
0	0	0	0	0	0	13	124	246	334	397	454	457	393	348	251	122	8	0	0	0	0	0	0
0	0	0	0	0	0	0	68	209	319	387	414	442	386	320	205	57	0	0	0	0	0	0	0
0	0	0	0	0	0	0	34	214	347	421	455	455	412	341	228	59	0	0	0	0	0	0	0

Geothermal Capacity, by Oilfield



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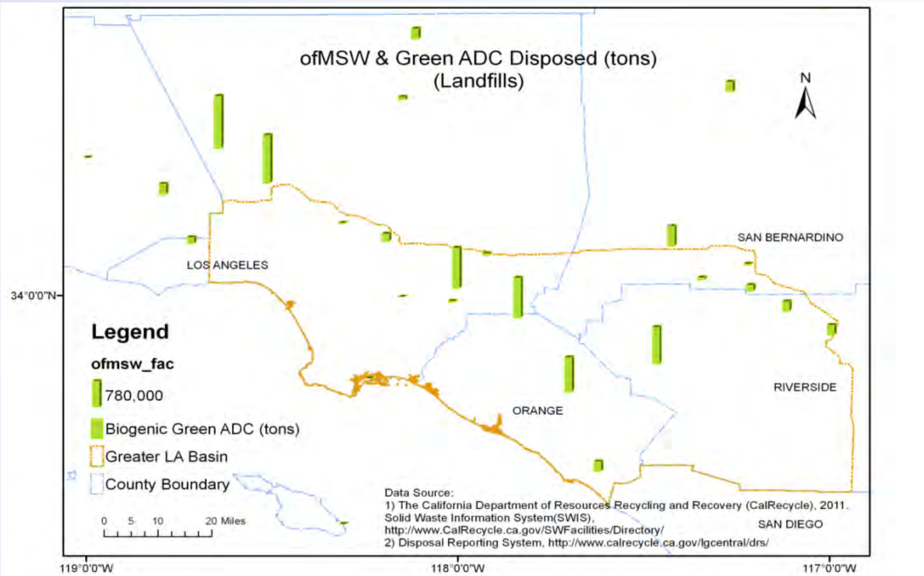

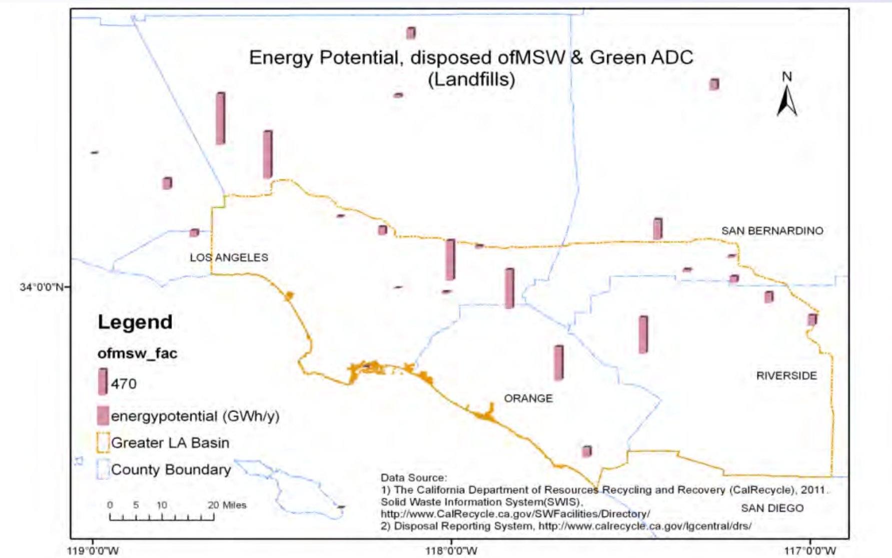

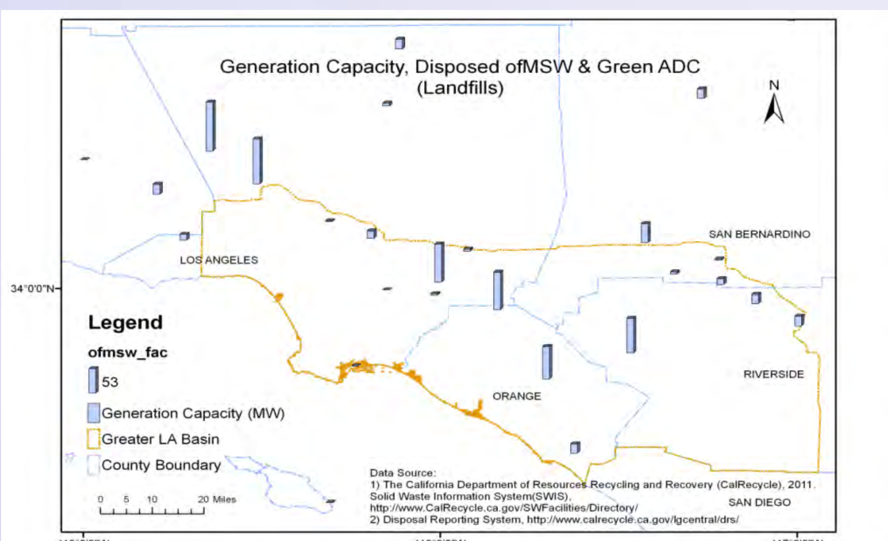

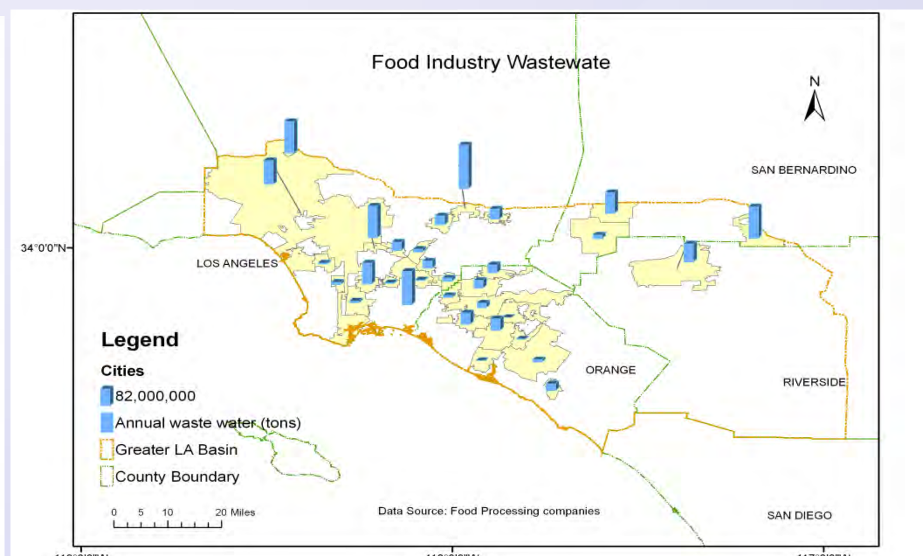

Bioenergy Potential in L.A. Basin

Playa del Rey / El Segundo (Hyperion WWTP)

Capacity (MW)	Energy (GWh/y @ 0.9 capacity factor)	Natural Gas Diplacement (MMscf/y)	CO_2 Offset (Tonnes/y)
21	165.6	1,733	97,833

Wilmington Study (JWPCP Waste Water Plant)

Capacity (MW)	Energy (GWh/y @ 0.9 capacity factor)	Natural Gas Diplacement (MMscf/y)	CO_2 Offset (Tonnes/y)
21	165.6	1,733	97,833

Yorba Linda Study Area (Olinda Alpha Landfill)

	Capacity (MW)	Energy (GWh/y @ 0.9 capacity factor)	Natural Gas Diplacement (MMscf/y)	CO2 Offset (Tonnes/y)
Current LFG power	37	291.7	3,053	172,373
Potential Energy from Waste Conversion	89	704.7	7,374	416,418

L.A. Basin: Combined Benefits

	MW	Natural gas Displaced (MMSCF/yr)	CO_2 Offset (Tonnes/yr)
Playa del Rey	41.1	2,674	153,978
Wilmington	855	45,304	2,556,400
Yorba Linda	731.3	22,891	1,292,635
Total	1,627.4	70,869	4,003,013

Potential Renewable Combinations

- Always site specific
- Coordinate and encourage generation to optimize for local resources
- Utilize flexible biomass and geothermal to support expansion of solar/wind systems
- Use solar and geothermal heat to supply thermal energy for biomass processes
- Power electronics on wind turbines can provide voltage support
- Wind and biomass are very compatible in terms of land use
- Wind and geothermal can coincide in complex topography
- Store solar by enhancing geothermal injection

Research Needs

- Develop standardized methods for optimizing an energy mix based on overall LCOE, emissions, maximized generation
- Coordinate resource assessment methods to achieve consistent metrics for generation outputs (i.e., MW and MWh), including storage
- Identify energy mix zones (analogous to climate zones) to optimize assessment and development efforts and streamline incentives.
- Incorporate demand data at fine spatial resolution. Opportunity to encourage distributed installations by power consumers.
- Region-specific distribution level integration studies, including smart grid technologies, vehicle-to-grid, and energy storage.

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9:00	Introduction and Overview
9:15	Integrated assessment of renewable technology options
10:15	Break
10:30	Assessment of Co-located renewable generation potential
11:00	**Assessment of geothermal in under-served regions**
11:30	Solar heating and cooling technology analysis
Noon	Lunch
1:15	California off-shore wind technology assessment
1:45	Technical assessment of small hydro
2:15	Biomass resources and facilities database update
2:45	Break
3:00	Assessment of sustainability for new/existing biomass energy
3:30	Biomass/MSW gap assessment and tech options for biogas clean-up
4:15	Future research recommendations
4:45	Closing

Assessment of Geothermal Resources In Under-served Regions

The goal of this task is to develop a methodology for assessing geothermal resources in regions that possess inadequate expert capability to undertake such assessments.

Many counties in California possess modest geothermal resources that, if developed, could significantly improve local and regional economic conditions. However, such locations commonly lack sufficient funds, indigenous knowledge and skills to plan, execute and analyze resource capacity and potential applications.

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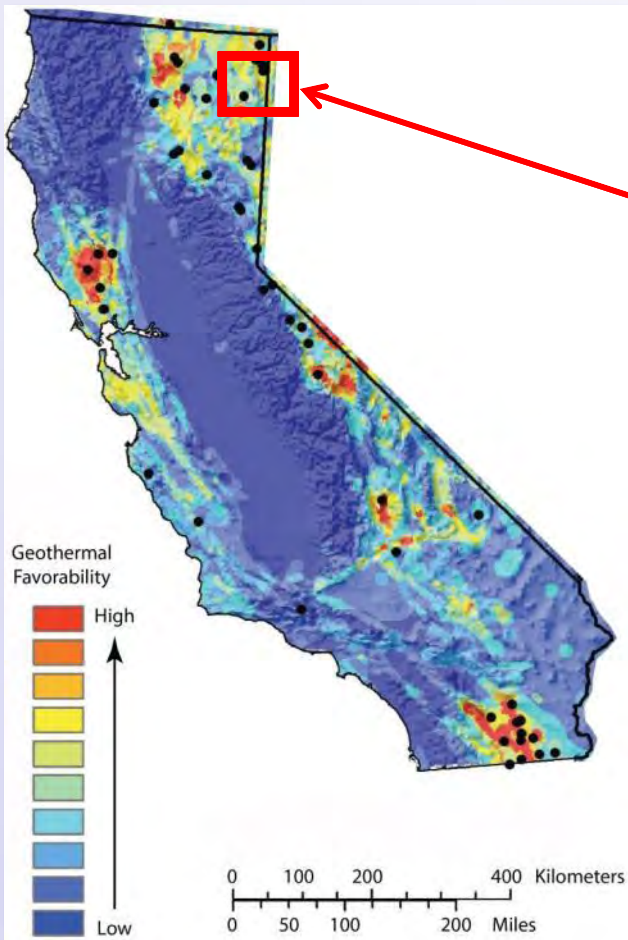
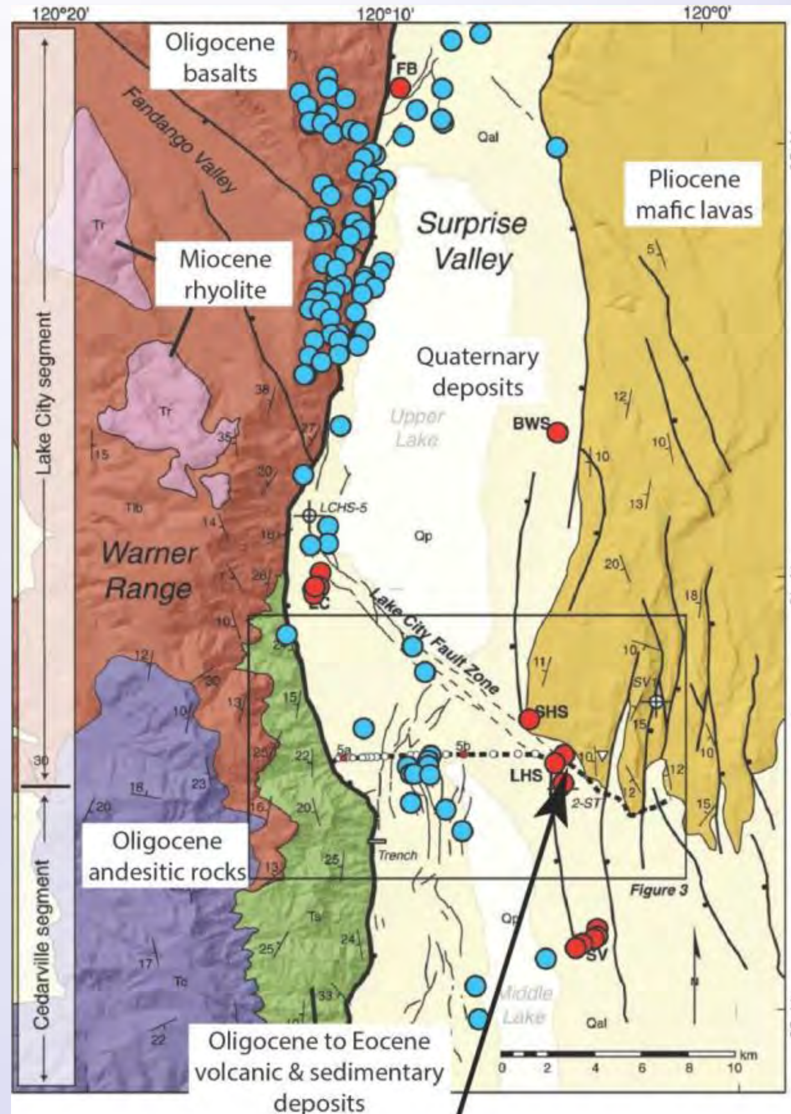
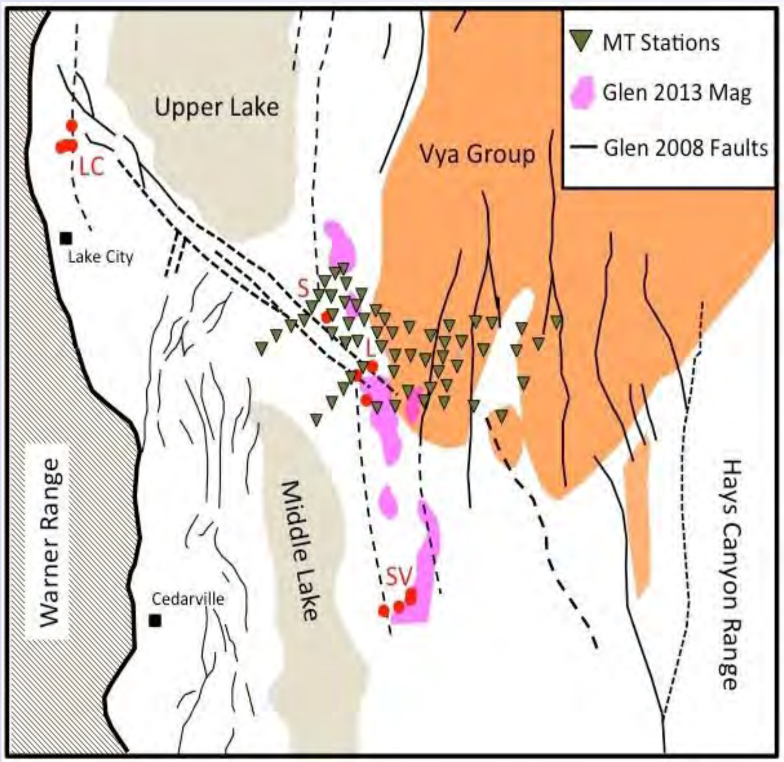
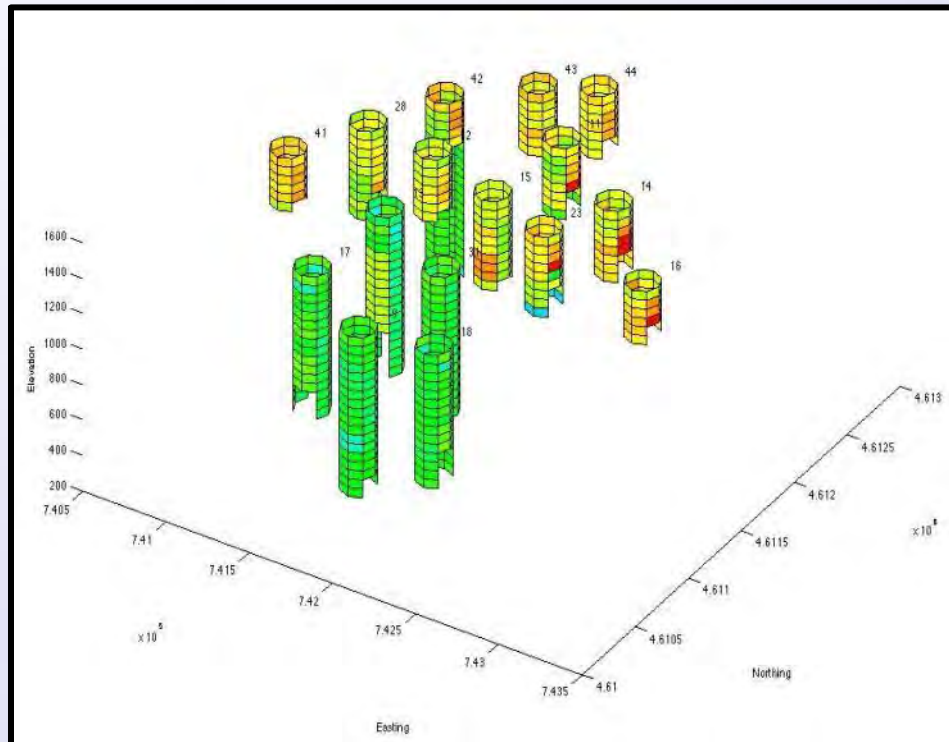
Selected site:
Surprise Valley (Alturas)



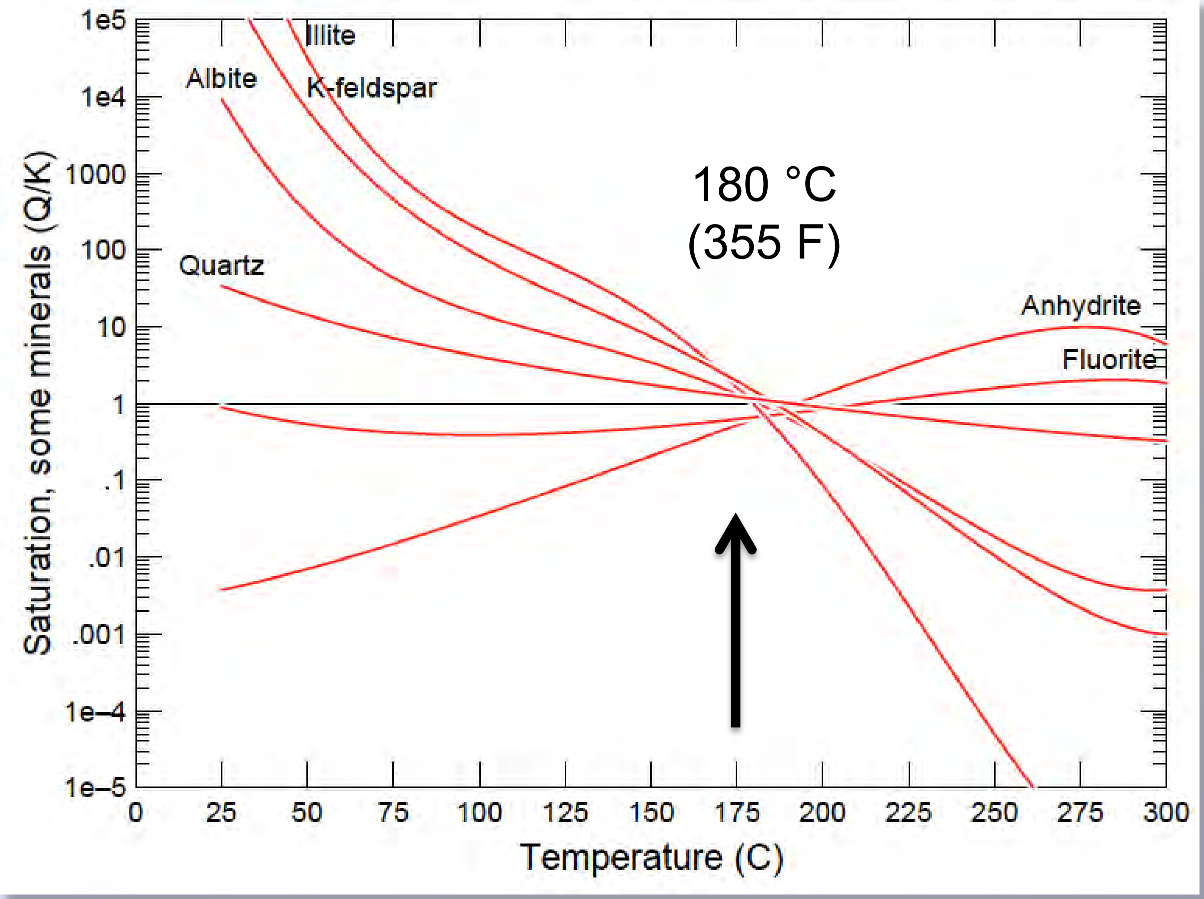


Magnetotelluric results, Samuel Hawkes





Geochemistry results, Carolyn Cantwell & Andrew Fowler



Presentation at Alturas City Hall, August 17, 2013

"The big highlight for us was the community meeting UC Davis held . . . It was standing room only . . . With that added confidence, two of our communities in Modoc County became proactive and answered a grant solicitation by the CEC. Both entries were awarded. "

- **Curt Rose *(resident)***

"This project was a great opportunity to . . . show me how I might tailor my research approach to produce a product that is useful to people outside of the academic realm."

- **Carolyn Cantwell *(M.Sc. candidate)***

"I strongly believe the ability to communicate science research to non-experts is a key . . . The Surprise Valley project has provided a unique forum to integrate these . . . important ideas."

- **Andrew Fowler *(Ph.D. candidate)***

9:00	Introduction and Overview
9:15	Integrated assessment of renewable technology options
10:15	Break
10:30	Assessment of Co-located renewable generation potential
11:00	Assessment of geothermal in under-served regions
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Solar Heating and Cooling Technology Analysis

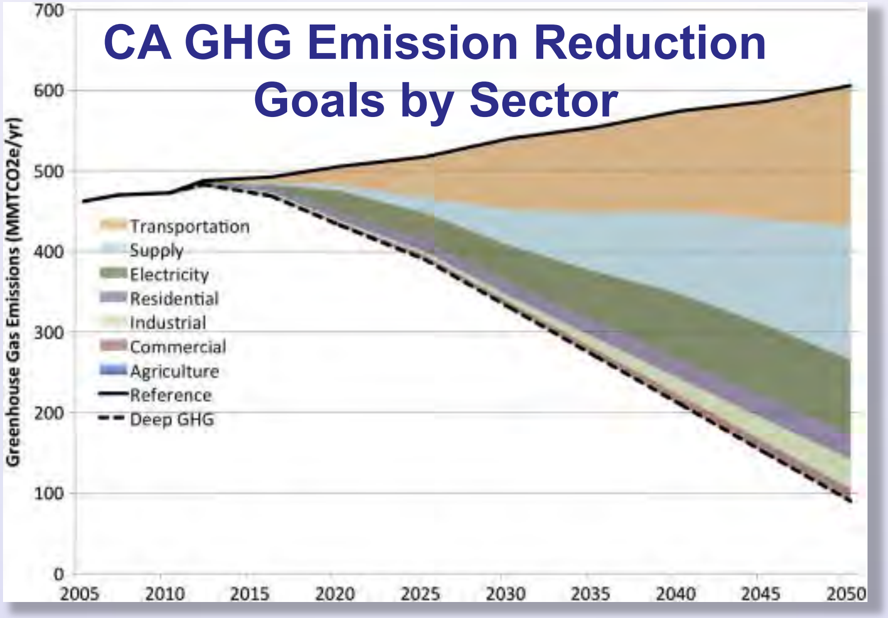
Agenda for this session:

1. Market Analysis
2. Solar Thermal (ST) Technologies
3. Industry Scenarios
4. Challenges and Opportunities
5. Q/A

Market Analysis

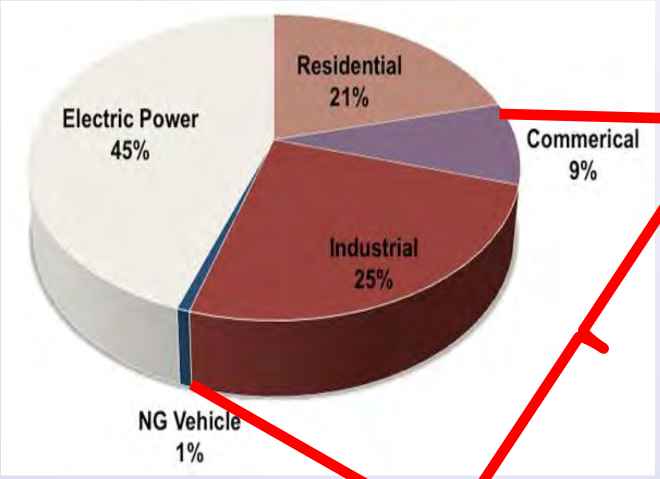
California Energy Efficiency and GHG Goals

- Integrated previous finding from Navigant and McCollum et al. (2012)



Navigant Consulting Inc. Nov. 2011, Analysis to Update Energy Efficiency Potential, Goals and Targets for 2013 and Beyond. http://www.cpuc.ca.gov/PUC/Energy+Efficiency/Energy+Goals+and+Potential+Studies.htm
David McCollum, Christopher Yang, Sonia Yeh, Deep Greenhouse Gas Reduction Scenarios for California — Strategic implication from the CA-TIMES energy-economic systems model. Energy Strategy Reviews, Vol 1, Issue 1, March 2012, Page 19-32

California Natural Gas Demand by Sector in 2012



Ref: Energyalmanac.ca.gov

Gas Consuption (in Millions of Therms) of Non-Residential Sections in California in 2012 (Source: ECDMS.Energy.Ca.Gov)

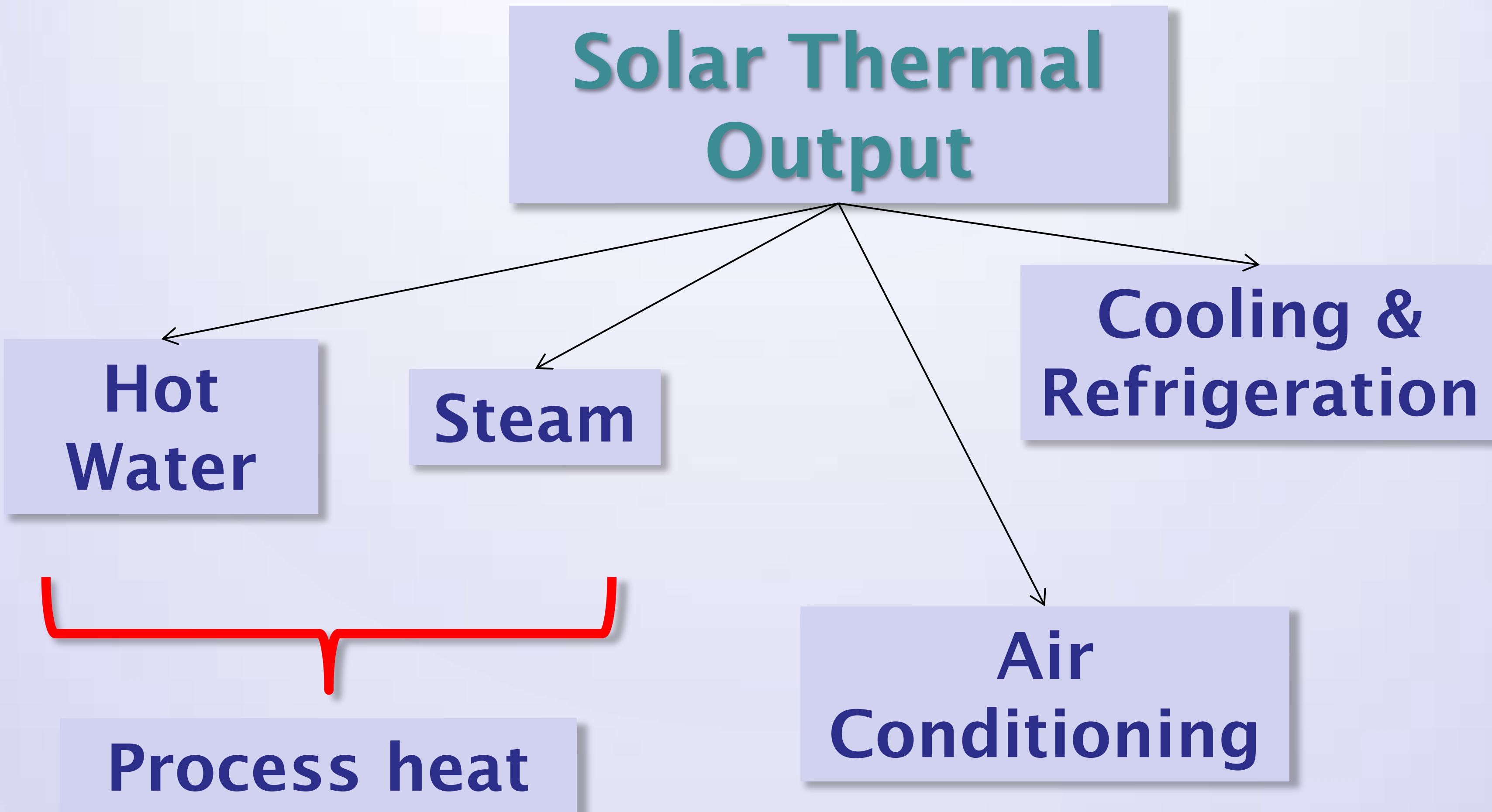
Utility Name	Commercial Building	Industry	Mining & Construction	Total Usage
Pacific Gas & Electric Company (PG&G)	**867.85**	**1746.38**	25.03	2639.26
San Diego Gas and Electric Company	**155.82**	22.16	3.78	181.76
Southern California Gas Company	**919.46**	**1592.65**	209.41	2721.53
Southwest Gas Corporation	41.69	4.43	0.82	46.94
Gas Producer	0.00	0.00	**2047.43**	2047.43
City of Palo Alto, Resource Mgmt	13.94	2.90	0.24	17.08
Long Beach Gas Department	26.07	5.36	0.00	31.43

Natural Gas Price in California

California Nautual Gas End-User Prices (per Thousand Cubic Feet) by Sector and Estimates for 2015, 2020, and 2025

End-User Sector	2010	2011	2012	2013	2015	2020	2025
Residential	$9.92	$9.93	$9.14	$10.94	$9.43	$10.04	$10.67
Commercial	$8.30	$8.29	$7.05	$8.05	$7.25	$7.87	$8.49
Industrial	$7.02	$7.04	$5.77	$6.61	$5.11	$5.73	$6.35
Power Generation	---	---	---	$4.13	$4.53	$5.13	$5.73
Enhanced Oil Recovery/Cogeneration	---	---	---	---	$4.65	$5.62	$5.87

Sources of Data: 1) EIA.Gov, 2) 2013 Natural Gas Issues, Trends, and Outlook Final Staff Report. California Energy Commission. CEC-200-2014-001-SF.


Solar Thermal Output
Hot Water
Steam
Cooling & Refrigeration
Air Conditioning
Process heat

Process Heat in the Industrial Sectors

Industrial Processes Requiring Process Heat

Industrial Process	Temperature (°C)	Industrial Sectors
Washing and Cleaning	40-90	Food and Beverages, Meat, Wine, Brewery, Textile, Pharmaceutical, Galvanizing and Electroplating
Sterilization	100-150	Food and Beverages, Pharmaceutical, Dairy, Tinned Food, Meat
Pasteurising	80-110	Food and Beverages, Pharmaceutical and Biochemical, Tinned Food
Drying, Concentrates, and Evaporation	30-180	Food and Beverages, Textile, Pharmaceutical, Wood, Dairy, Creamary, Plastics
Cooking	60-100	Food and Beverages, Tinned Food, Paper, Meat
Boiling	95-105	Food and Beverages, Chemical Industry
Boiler Feed Water Preheating	30-100	Food and Beverages, Chemical Industry, Textile, Dairy, Paper, Wood
Bleaching	60-150	Textile, Paper
Dyeing	100-160	Textile
General Process Heat	120-180	Chemical Industry, Plastic

Sources: 1) iea.org, 2) S. Mekhilef, et al, Renew. & Sust. Energy Rev. (2011), 3) Large Scale Solar Thermal Systems Design Handbook

Energy Consumption by Food Industry Sector

Energy Consumption in Different Industry Sectors

Industry	Annual Average Gas Consuption (Million Therm)	Annual Average Electricity Consuption (Million kWh)
Food and Vegetable Food Processors in California	350	700
Cheese Producers in California	43	583
Milk Powder/Butter Producers in California	33	130
Meet (Beef) Sector in California	5	88
Meet (Poultry) Sector in California	40	360
Wineries in California	23	406
Rice Sector in California	41	316
Breweries	1.5 Therms/barrel	22 kWh/barrel

Resources: 1) Technology Roadmap: Energy Efficiency in California's Food Industry CEC-500-2006-073 2) Brewers Association Energy Usage, GHG Reduction, Efficiency and Load Management Manual

Agenda for this session:

1. Market Analysis
2. **Solar Thermal (ST) Technologies**
3. Industry Scenarios
4. Challenges and Opportunities
5. Q/A

Solar Thermal Technologies

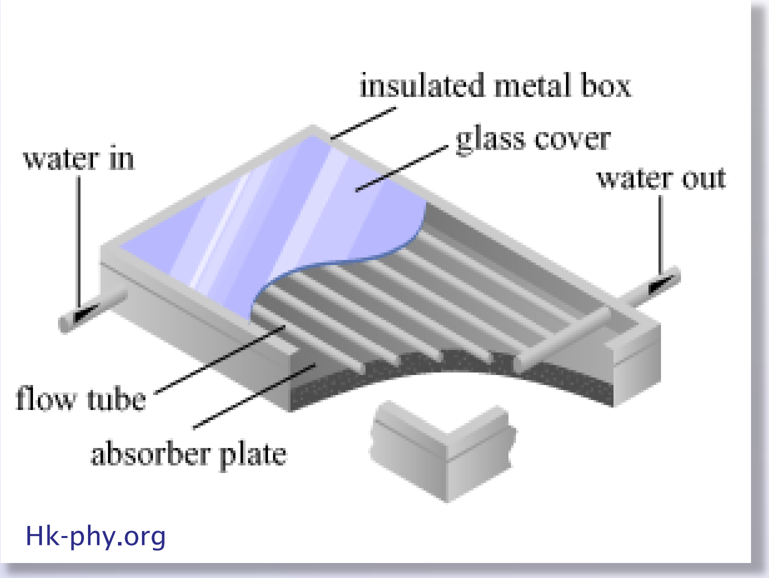
Solar Thermal Technologies

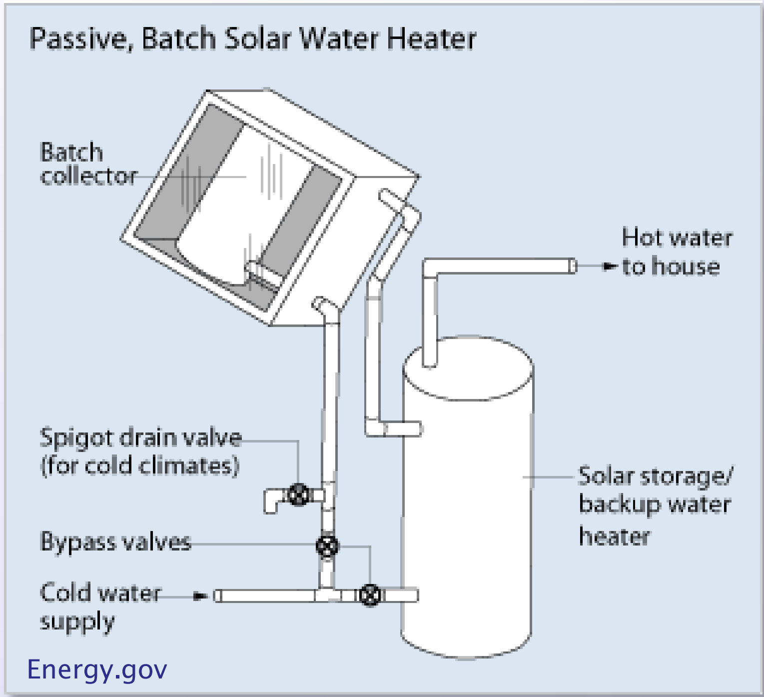
	Technology	Technology Readiness Level	Sun Tracking	Tempereature Range (°C)
Non-Concentrating	Flat Plate Collector	TRL 9	No	30-80
	Evacuated Tube Collector	TRL 9	No	50-200
	Batch Water Heater	TRL 7	No	30-50
Concentrating	Parabolic Trough Collector	TRL 9	Single-axis	60-300
	Compound Parabolic	TRL 5	No	60-240
	Linear Fresnel Reflector	TRL 7	Single-axis	60-250
	Parabolic Dish	TRL 7	Two-axis	100-500
Hybrid Photovoltaic (PV)-Thermal	Photovoltaic-Thermal (PV/T) Panels	TRL 8	No	30-80
	Parabolic Trough PV/T	TRL 8	Single-axis	30-110
	Parabolic Dish PV/T	TRL 7	Two-axis	30-100

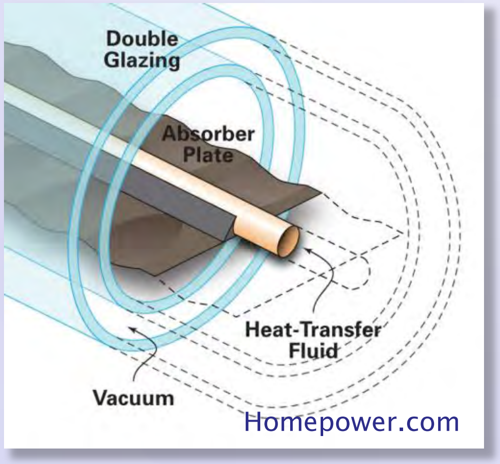
How to choose the proper technology?

a) Required Temperature, b) Available land or rooftop space, c) Electricity and Natural Gas Consumption, d) Capital Cost, e) Volume of hot water/steam demand, f) Maintenance, g) Direct vs diffuse sun radiation

Non-Concentrating Technologies

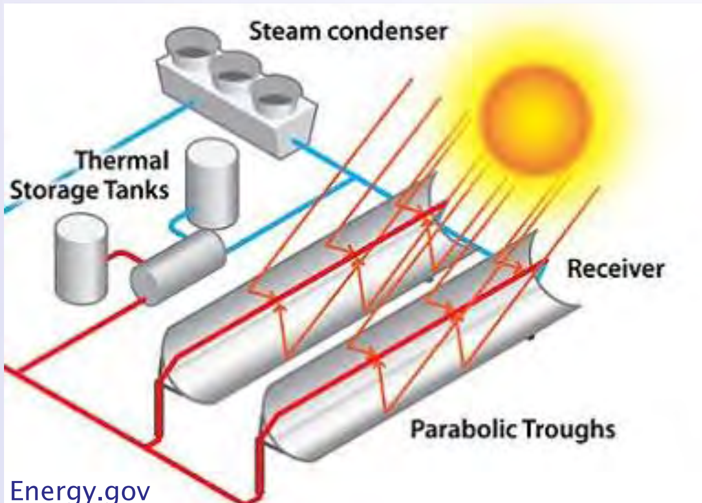


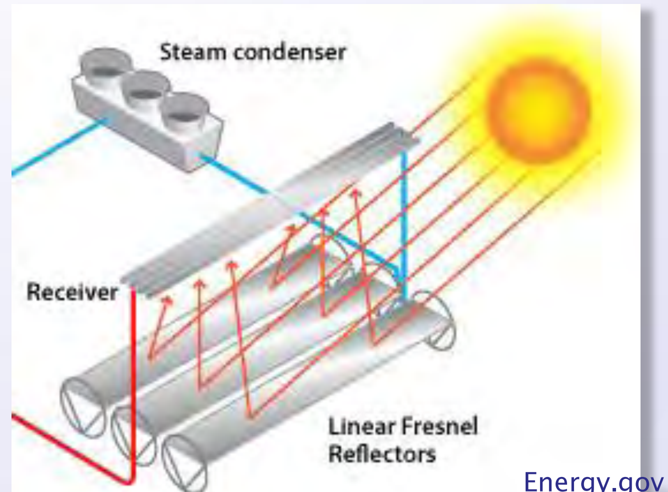


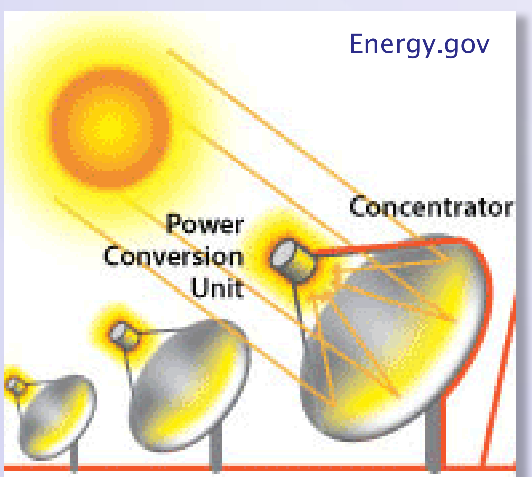


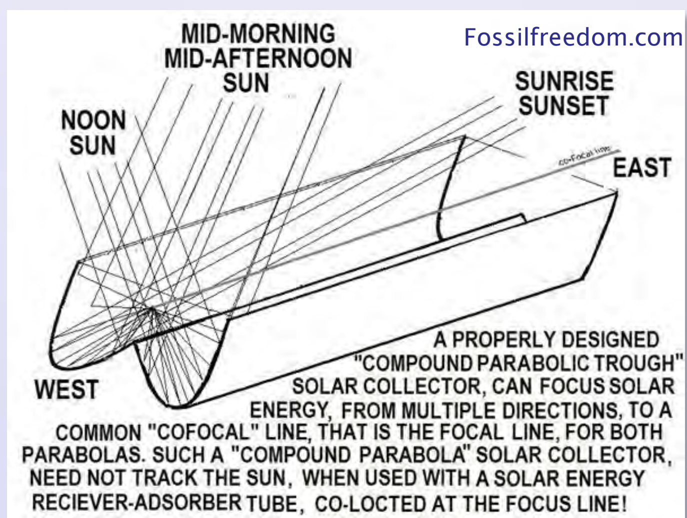
1. Lower Temperatures
2. Easy to install
3. Less Maintenance due to no tracking mechanism

Concentrating Technologies



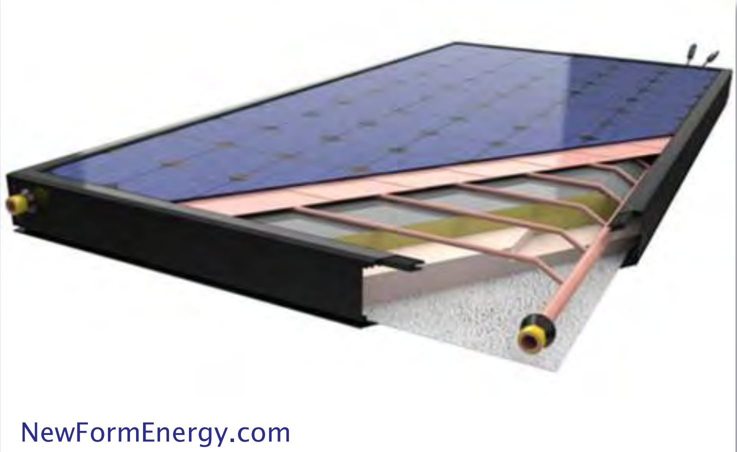


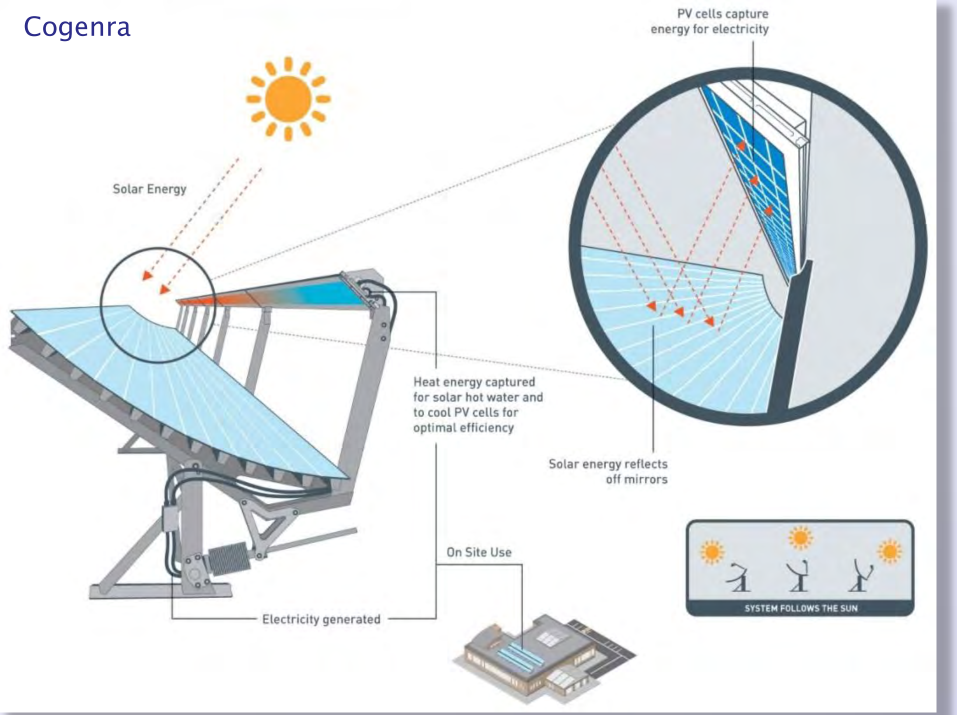


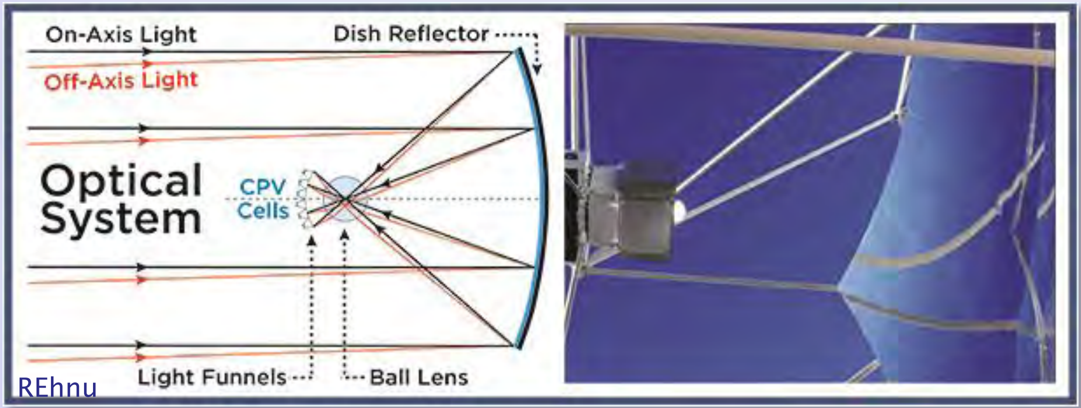


1. **Suitable for Steam production**
2. **Higher capital cost and O&M Cost**
3. **Land Requirement**
4. **Require Direct Sun Radiation**

Hybrid Technologies







1. Combined Production of electricity and Thermal Energy
2. Still young technologies
3. Capital cost and maintenance costs are higher

Agenda for this session:

1. Market Analysis
2. Solar Thermal (ST) Technologies
3. **Industry Scenarios**
4. Challenges and Opportunities
5. Q/A

Industry Scenarios

Scenarios for Currently Available Industries

- **Self-assessment:** Each company can use some guidelines to have a rough estimate for employing Solar Thermal Technologies

Evaluation of monthly Natural Gas and Electricity Consumption → Required Temperatures → Selection of Compatible Solar Thermal Technologies → System technical and economic analysis

↓

← More detailed analysis by contacting solar thermal companies ← Strategies for integration to the currently available processes and equipment

Scenarios for Plants "Under Design"

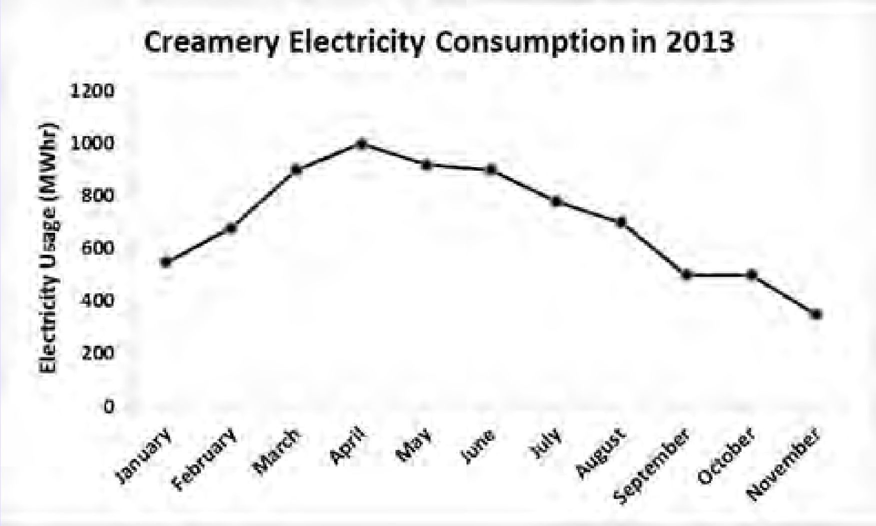
1.) Increasing the awareness of the companies in charge of engineering design of plants and processes, on the advantages of integration of Solar Thermal technologies the plant.

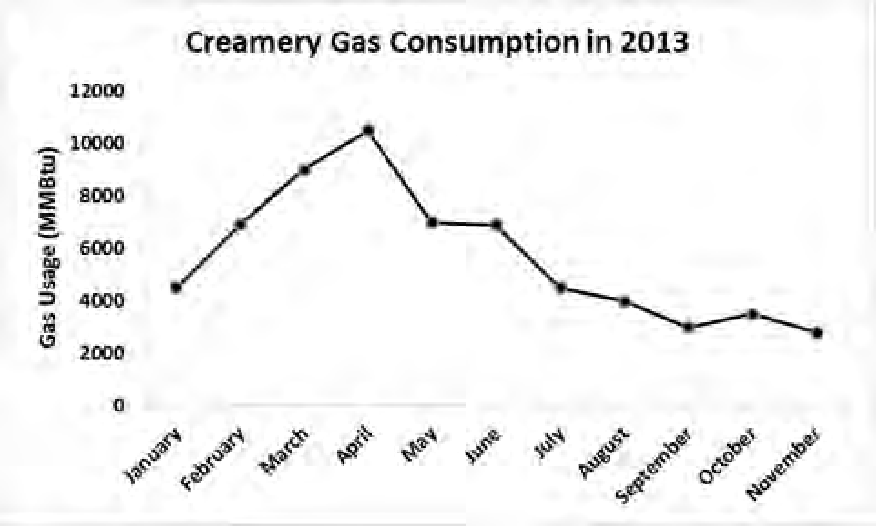
2.) Additional incentives for newly-built plants to incorporate Solar Thermal technologies.

3.) Formation of a community of solar thermal companies, engineering companies, and boiler companies (i.e., more integrated engineering designs).

Case Study: Design for a Creamery in North California

- Balancing Plant Creamery: Converting extra milk to cream, butter, concentrated milk, and dry powder milk.





Case Study: Design for a Creamery in North California – Different Scenarios

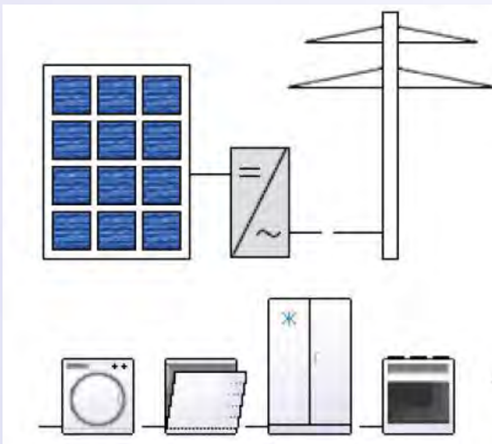
1) Photovoltaic (PV) panels for production of the electricity

2) Evacuated Tube Solar Thermal panels for production of hot water

3) Photovoltaic-Thermal (PV/T) panels for production of both electricity and hot water

We considered the installation of 10 panels for each scenario

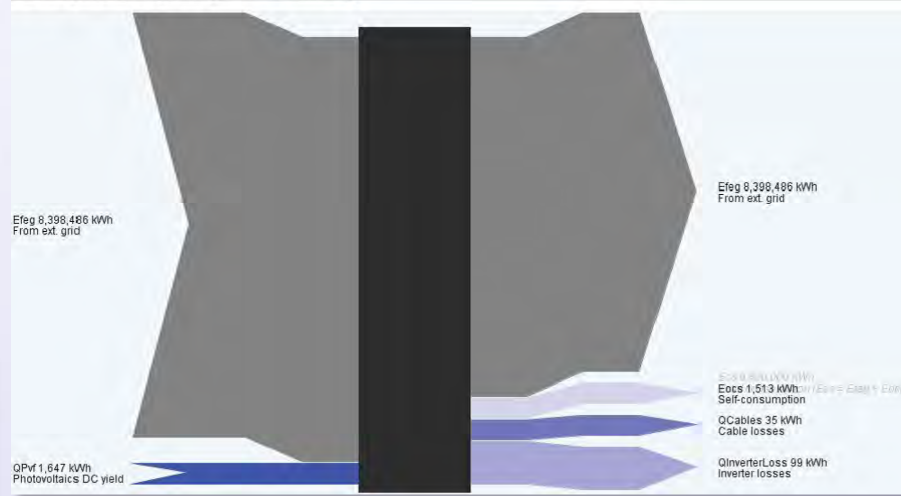
Case Study: Design for a Creamery in North California – PV Scenario



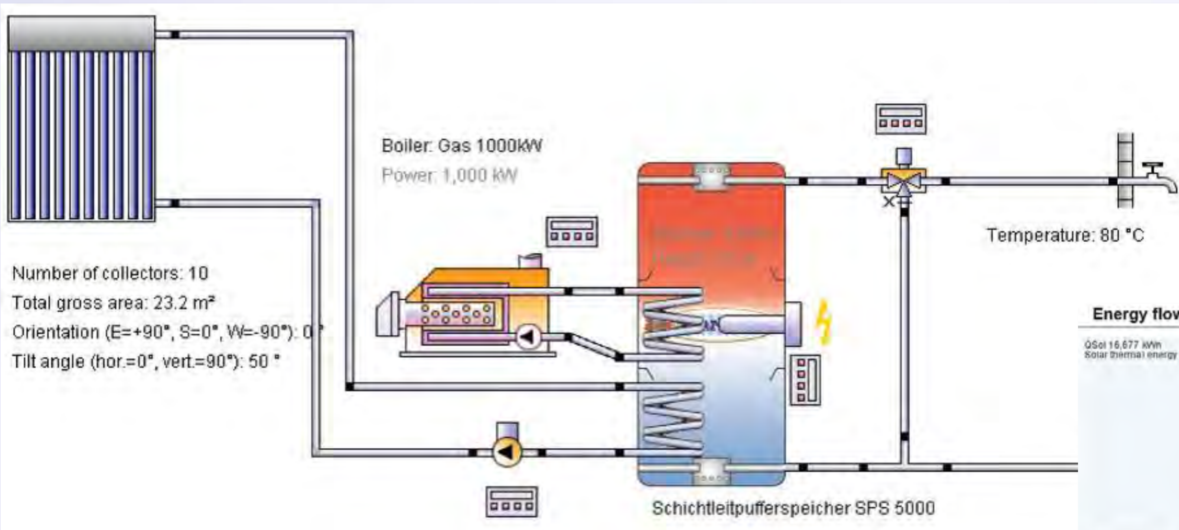
Overview photovoltaics (annual values)

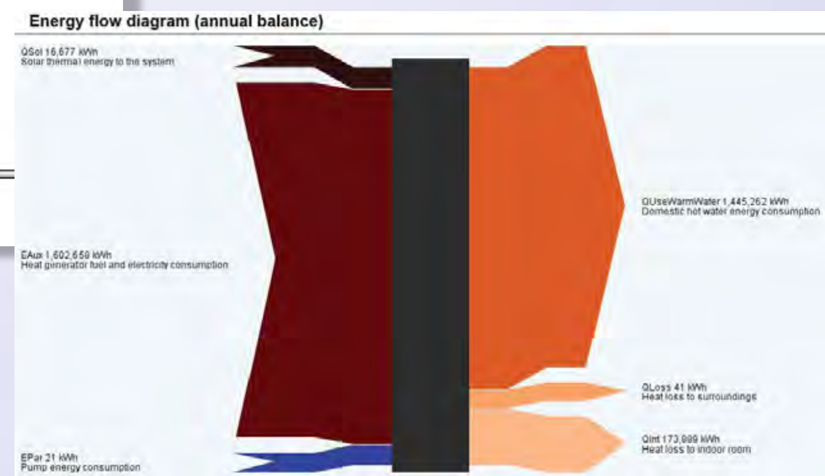
Total gross area	7.4 m²
Energy production DC [Qpvf]	1,646.6 kWh
Energy production AC [Qinv]	1,513.2 kWh
Total nominal power generator field	1 kW
Performance ratio	74.8 %
Specific annual yield	1,441.2 kWh/kWp/a
Phase imbalance	0.0001 kVAh
Reactive energy [Qinvr]	0 kvarh
Apparent energy [Qinva]	1,513.2 kVAh
CO2 savings	811.7 kg

Energy flow diagram (annual balance)



Case Study: Design for a Creamery in North California – Evacuated Tube Scenario

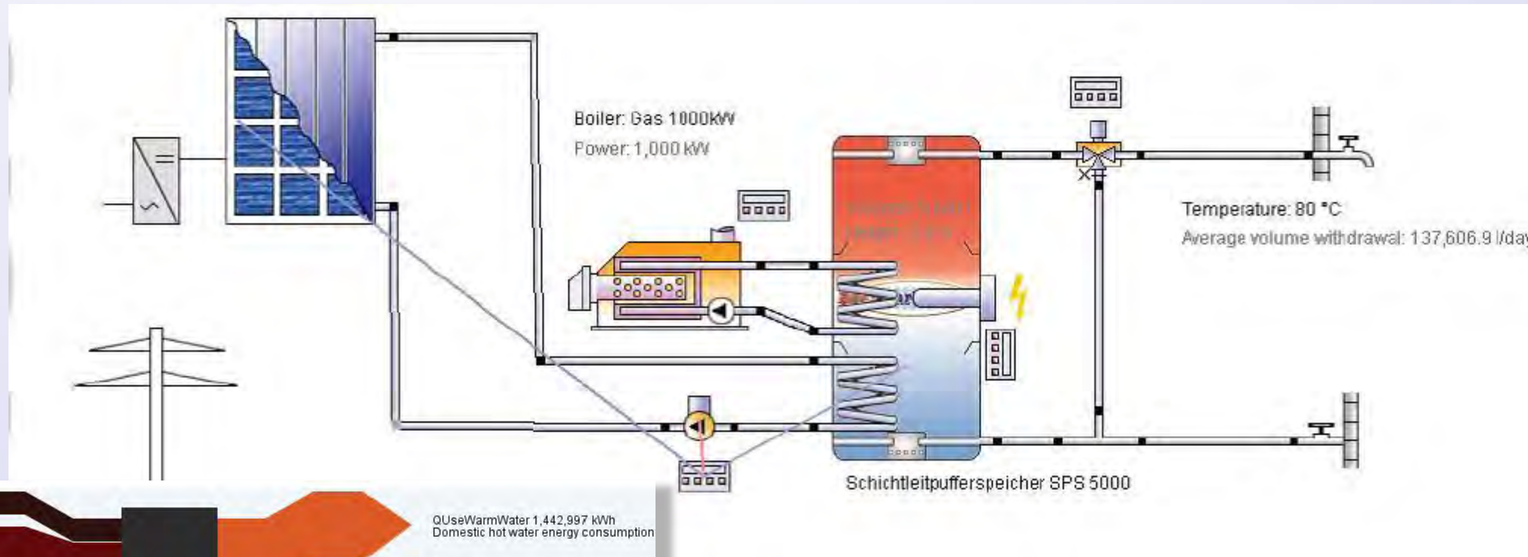


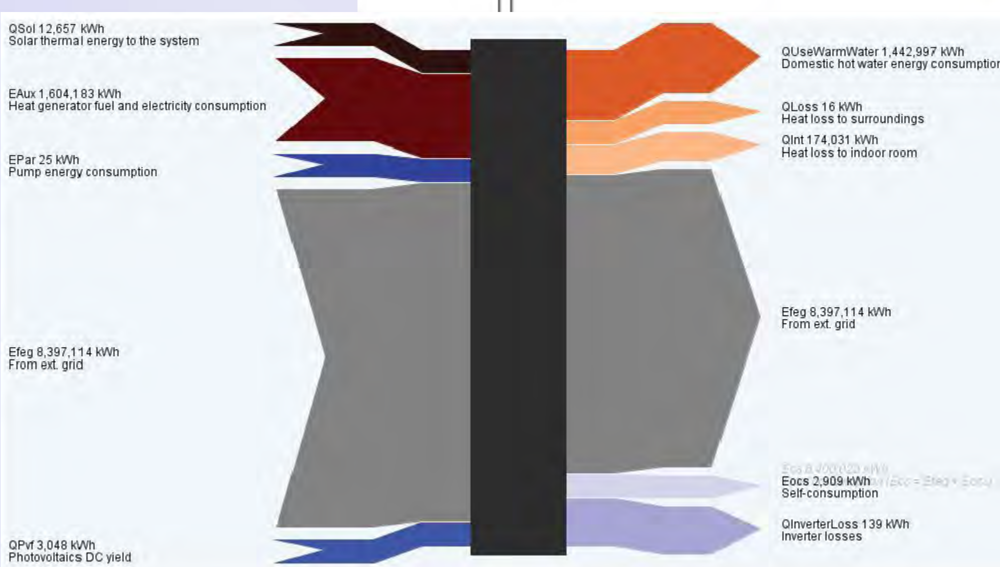


Overview solar thermal energy (annual values)

Collector area	23.2 m²
Solar fraction total	1.2%
Total annual field yield	16,676.6 kWh
Collector field yield relating to gross area	718.8 kWh/m²/Year
Collector field yield relating to aperture area	1,179.4 kWh/m²/Year
Max. fuel savings	1,764.7 m³(gas): [Natural gas H]
Max. energy savings	18,529.6 kWh
Max. reduction in CO2 emissions	4,291.2 kg

Case Study: Design for a Creamery in North California – PV/T Scenario





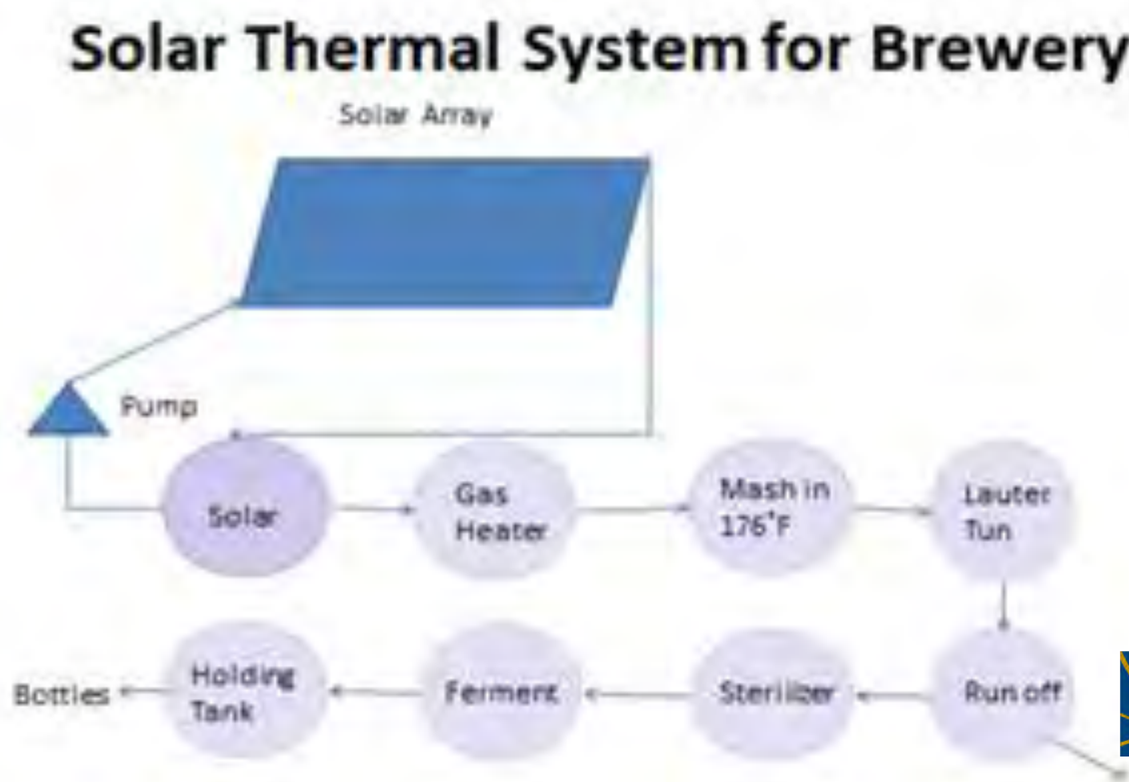
Case Study: Design for a Creamery in North California – PV/T Scenario (cont'd)

Overview solar thermal energy (annual values)	
Collector area	13.3 m²
Solar fraction total	0.9%
Total annual field yield	12,657.3 kWh
Collector field yield relating to gross area	951.7 kWh/m²/Year
Collector field yield relating to aperture area	966.2 kWh/m²/Year
Max. fuel savings	1,339.4 m³(gas): [Natural gas H]
Max. energy savings	16,973.1 kWh
Max. reduction in CO2 emissions	3,257 kg

Overview photovoltaics (annual values) (From PVT collector)	
Total gross area	13.3 m²
Energy production DC [Qpvf]	3,048.2 kWh
Energy production AC [Qinv]	2,909.4 kWh
Total nominal power generator field	1.8 kW
Performance ratio	85.1 %
Specific annual yield	1,616.3 kWh/kWp/a
Phase imbalance	0 kVAh
Reactive energy [Qinvr]	0 kvarh
Apparent energy [Qinva]	0 kVAh
CO2 savings	1,560.6 kg

Case Study: White Labs Brewery - Model

- 176˚F in the mash tank, 180˚F for dish/bottle washing.
- 70% target solar fraction
- TRNSYS model



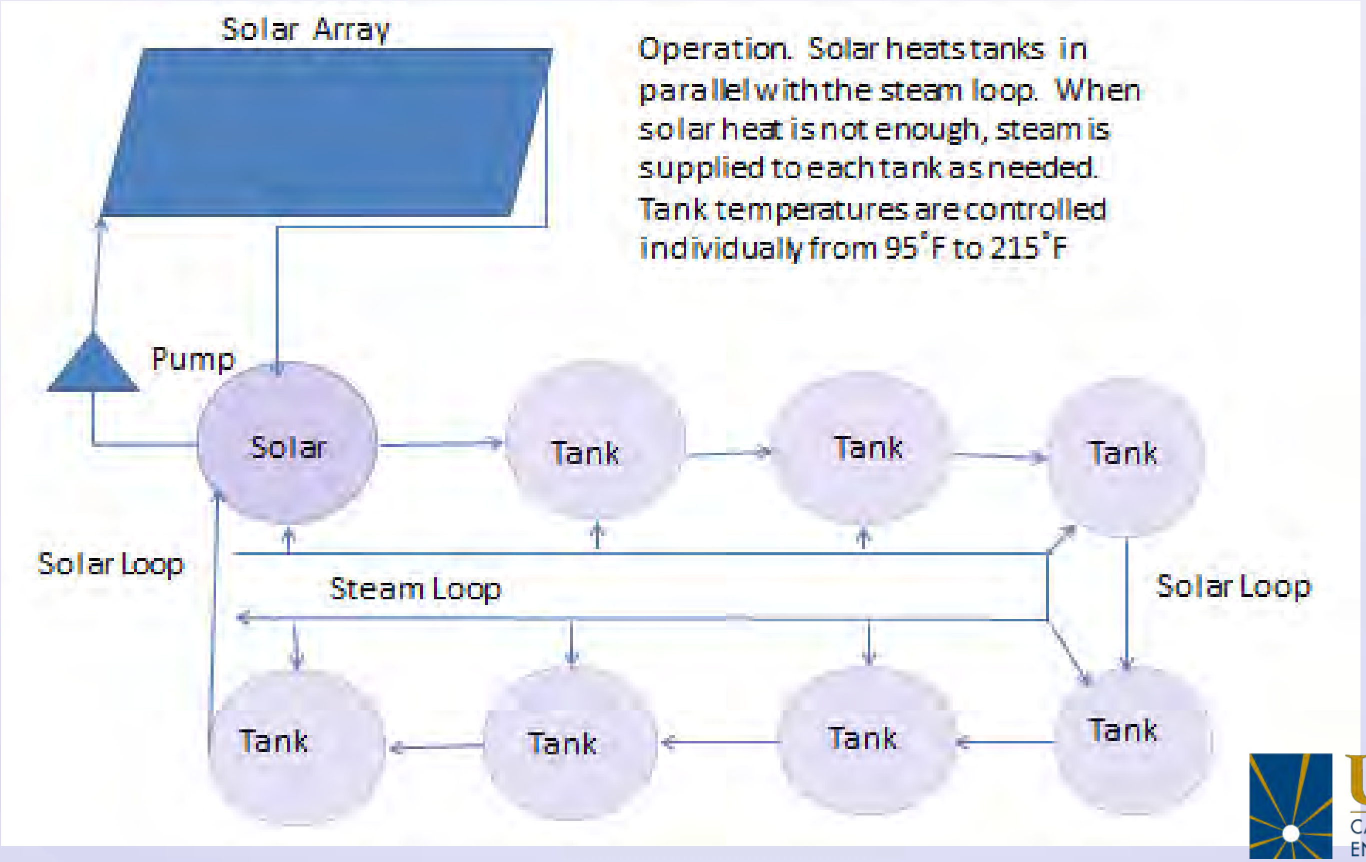
Case Study: White Labs Brewery - Results

- Propylene glycol
- 1280 sqft solar system at $100/sf
- 2-wall heat exchanger on collector loop
- Solar and storage tanks separate

Install Cost	$128,000
CSI Thermal Incentive	($72,432)
Federal ITC	($38,400)
Net Cost of System	$17,168
Annual Savings	$4,985
Simple Payback	3.4 Years
Payback w/o CSI, ITC	26 Years

Case Study: Navy Fleet Readiness Center - Model

- Cleaning and plating for aircraft refurbishment

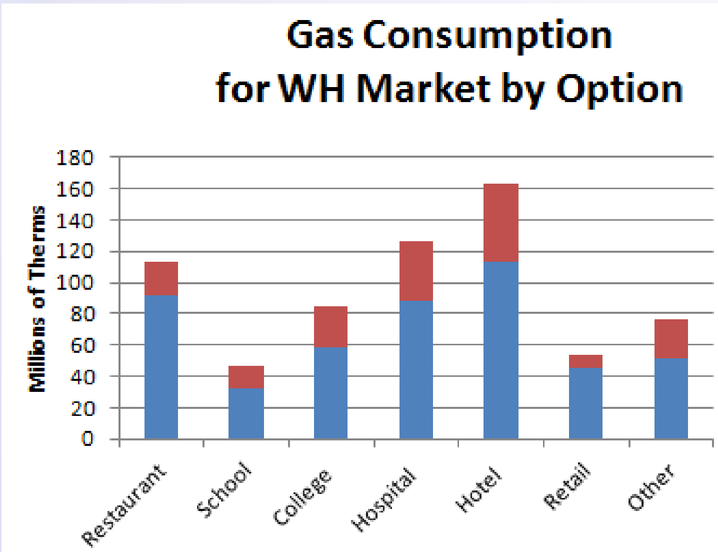


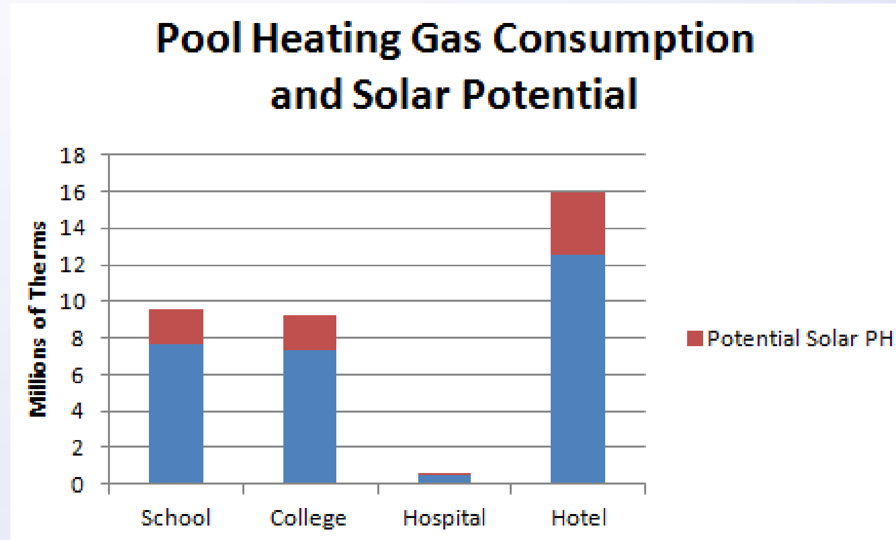
Case Study for Navy Fleet Readiness Center - Results

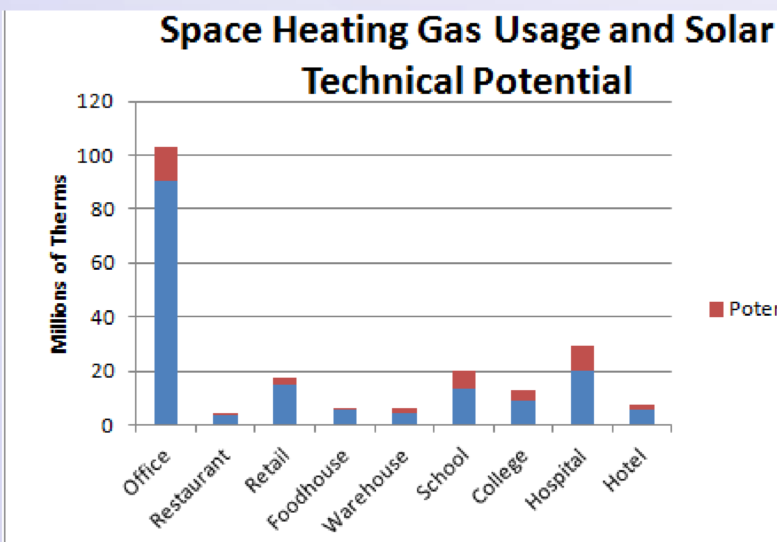
- Drainback system
- Boiler backup
- 276 x 40 sq ft collectors
- Storage 12,000 gallons
- Set point temperature = 190˚F

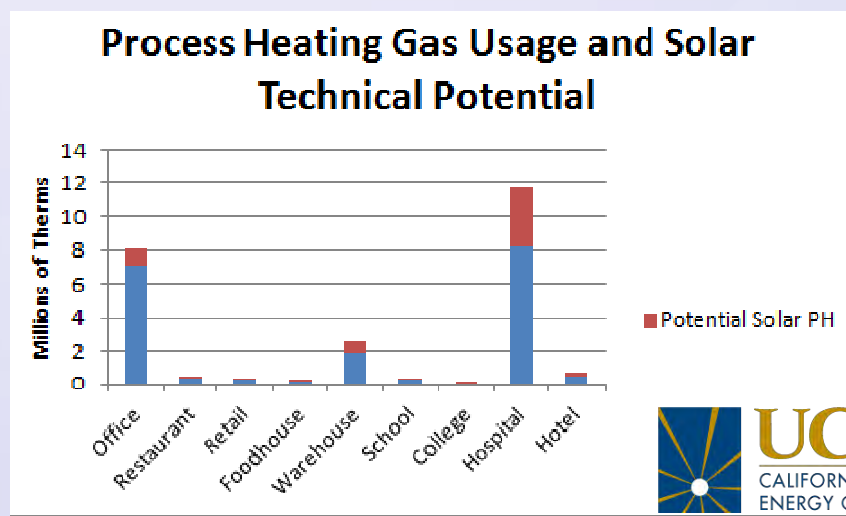
Installed Cost	($1,108,100)
CSI Thermal Incentive	$500,000
Net Cost of System	($608,100)
Annual Savings	$35,337
Simple Payback (vs Steam at $5.66/therm)	3.4 Years
Simple Payback (w/ Steam at $1/therm)	17.2 Years

Non-DHW Solar Thermal Potentials









Agenda for this session:

1. Market Analysis
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4. **Challenges and Opportunities**
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Challenges and Opportunities

Challenges and Opportunities

- Cheap price of natural gas and low motivation for decreasing natural gas consumption
- Payback time → Soft costs
- Integration of solar technologies to the current processes
- Incentives for newly built plants
- More interaction with the plant EPC
- Incentives for decreasing carbon foot print

Questions & Answers:
Solar Heating and Cooling Technology Analysis

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California Renewable Energy Center

9:00	Introduction and Overview
9:15	Integrated assessment of renewable technology options
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Lunch break

Program will resume at 1:15 pm

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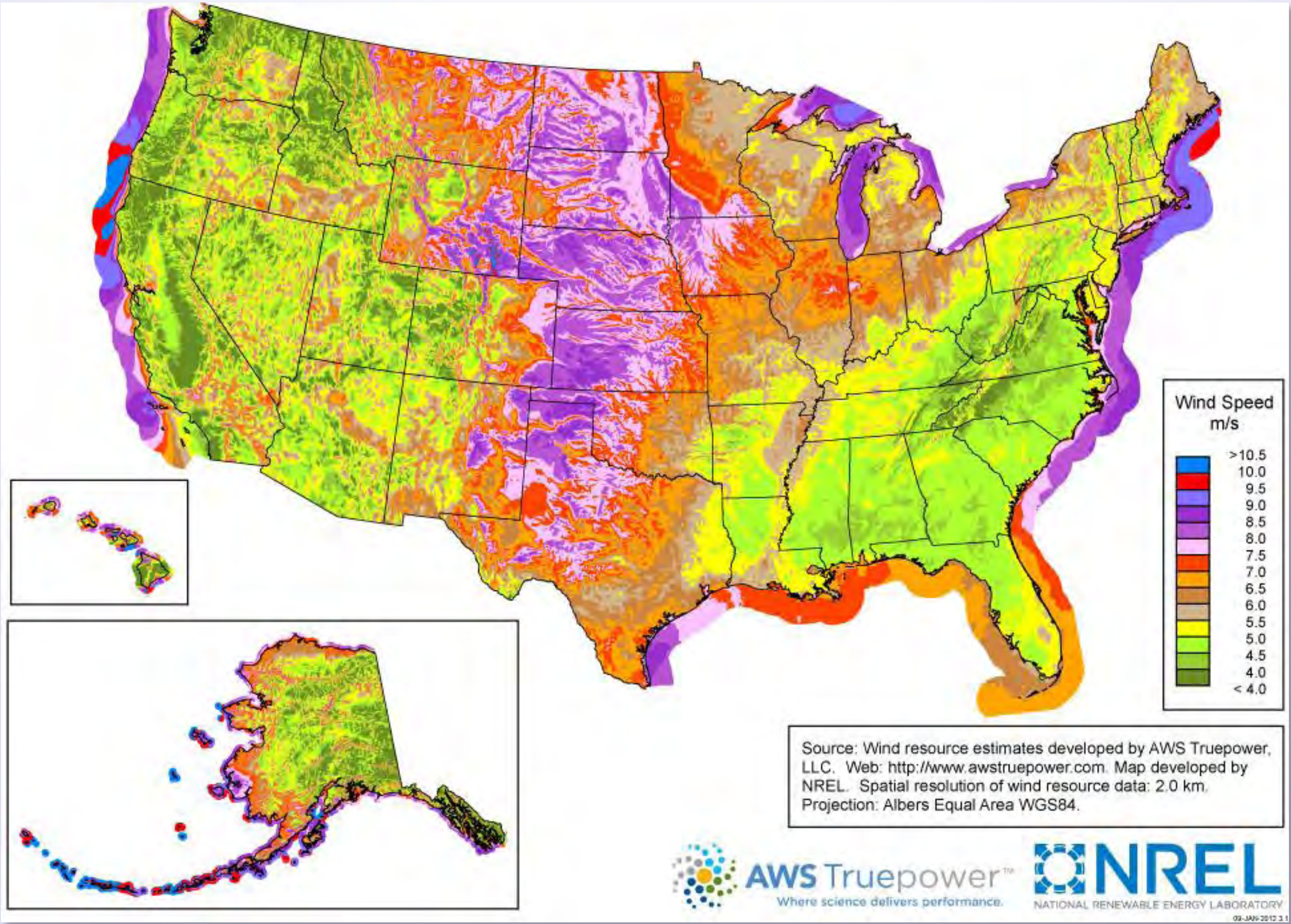
California Off-shore Wind Technology Assessment

Why Offshore Wind?

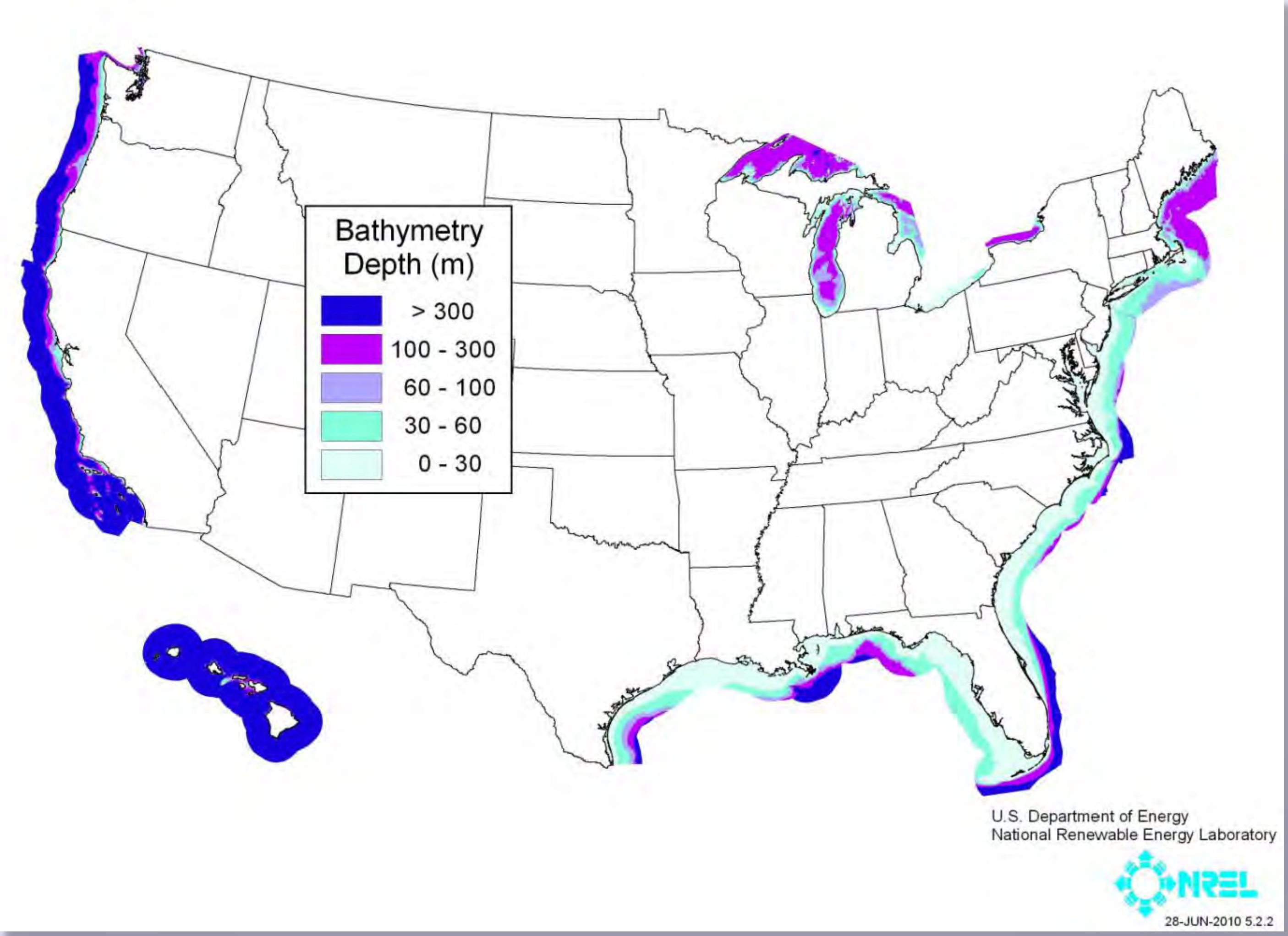
- Terrestrial wind power sites saturated
- Excellent wind resource
  - High wind speeds
  - Low turbulence
  - Near load centers
- Remotely located
- No road transportation constraints
  - Larger turbines
- Local economic benefits
  - Jobs
  - Infrastructure
  - Taxes

U.S. Onshore & Offshore Wind Resource



U.S. Offshore Bathymetry

Source: Schwartz et al., 2010



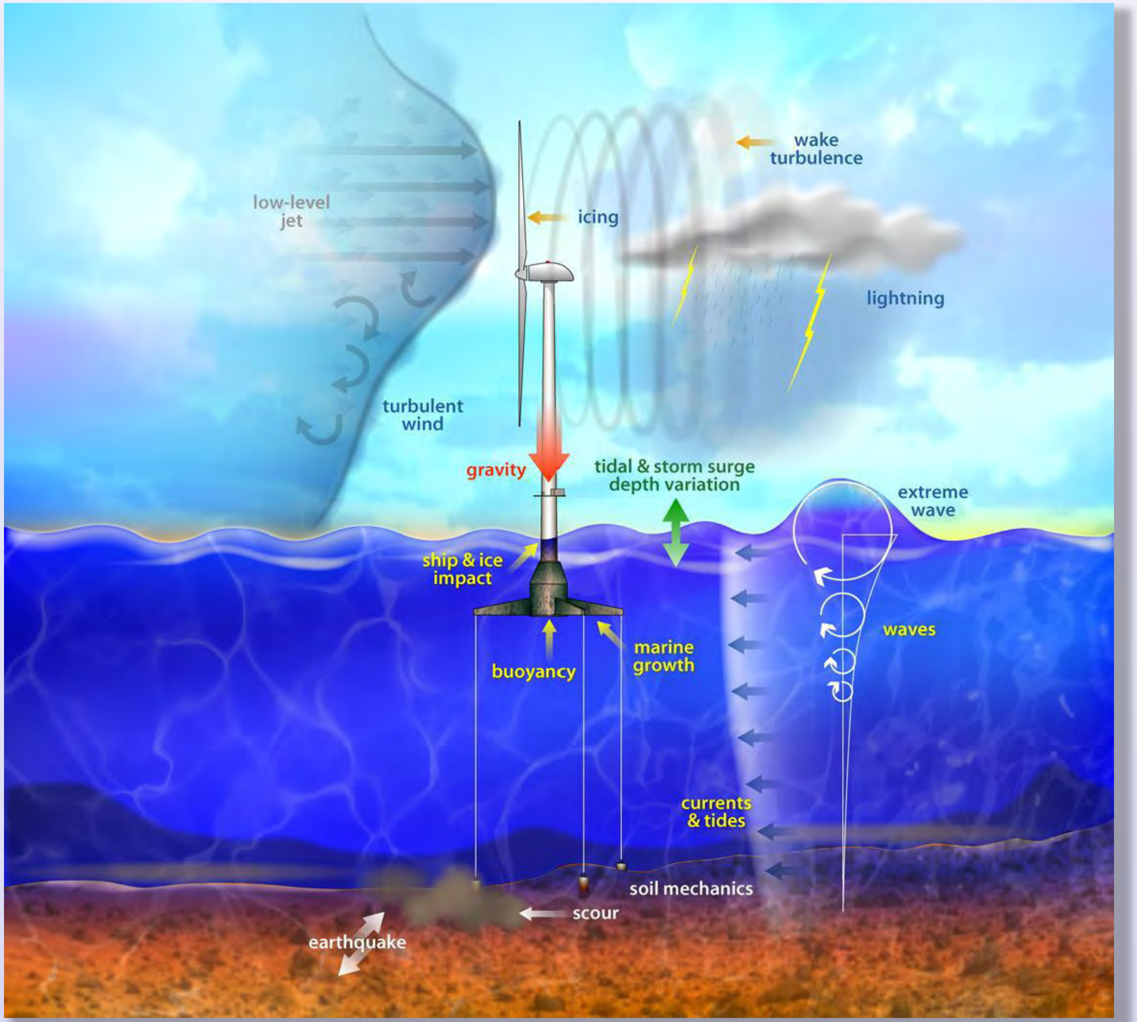
U.S. Raw Wind Potential

Source: Elliott et al., 2011

	GW by Depth (m)			
Region	**0-30m**	**30-60m**	**>60m**	**Total**
New England	100.2	136.2	250.4	486.8
Mid-Atlantic	298.1	179.1	92.5	569.7
South Atlantic Bight	134.1	48.8	7.7	190.7
California	4.4	10.5	573.0	587.8
Pacific Northwest	15.1	21.3	305.3	341.7
Great Lakes	176.7	106.4	459.4	742.5
Gulf of Mexico	340.3	120.1	133.3	593.7
Hawaii	2.3	5.5	629.6	637.4
Total	**1,071.2**	**627.9**	**2,451.2**	**4,150.3**

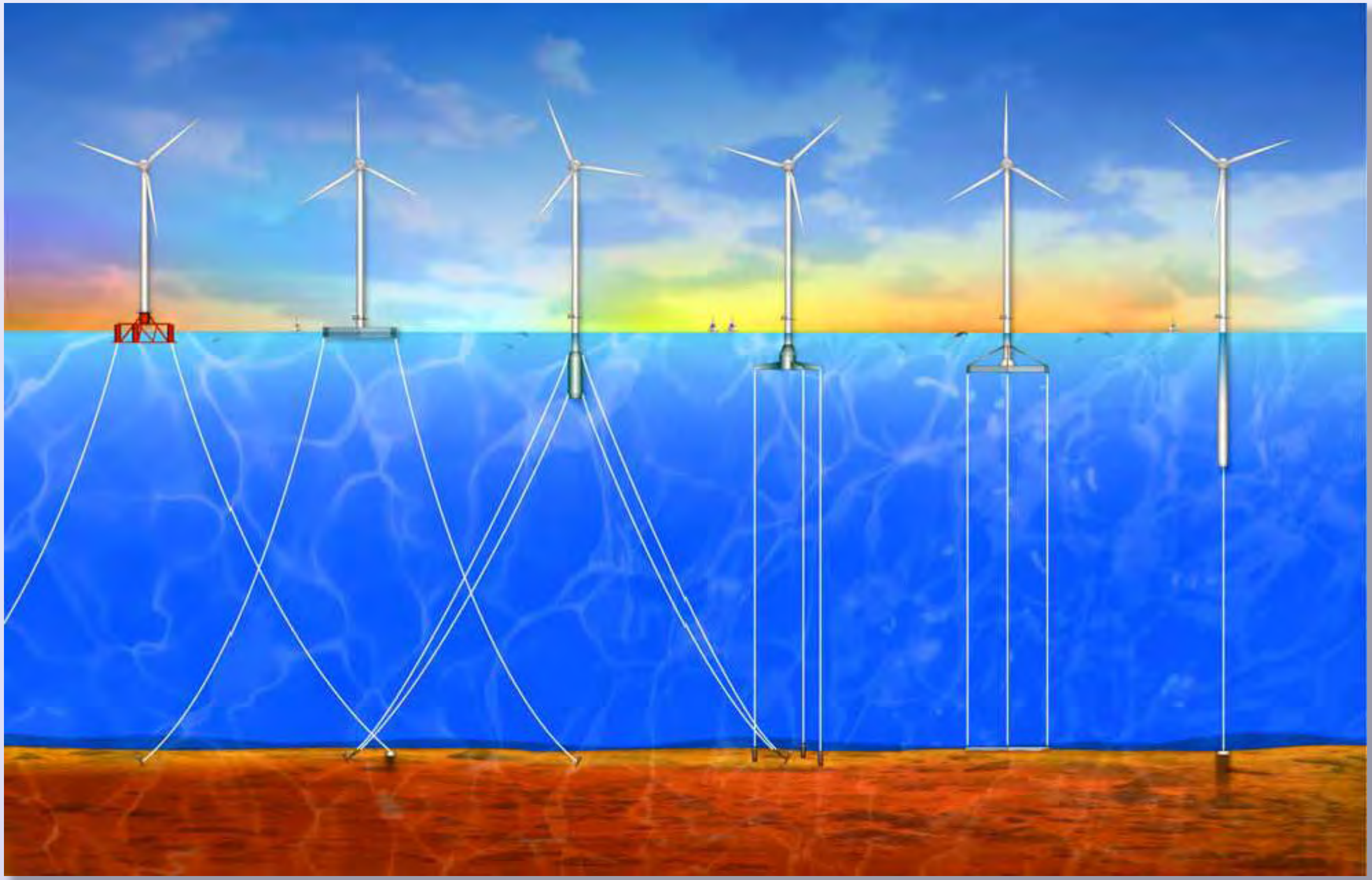
Offshore Wind Operating Environment

Source: NREL



Wind Turbine Floating Platforms

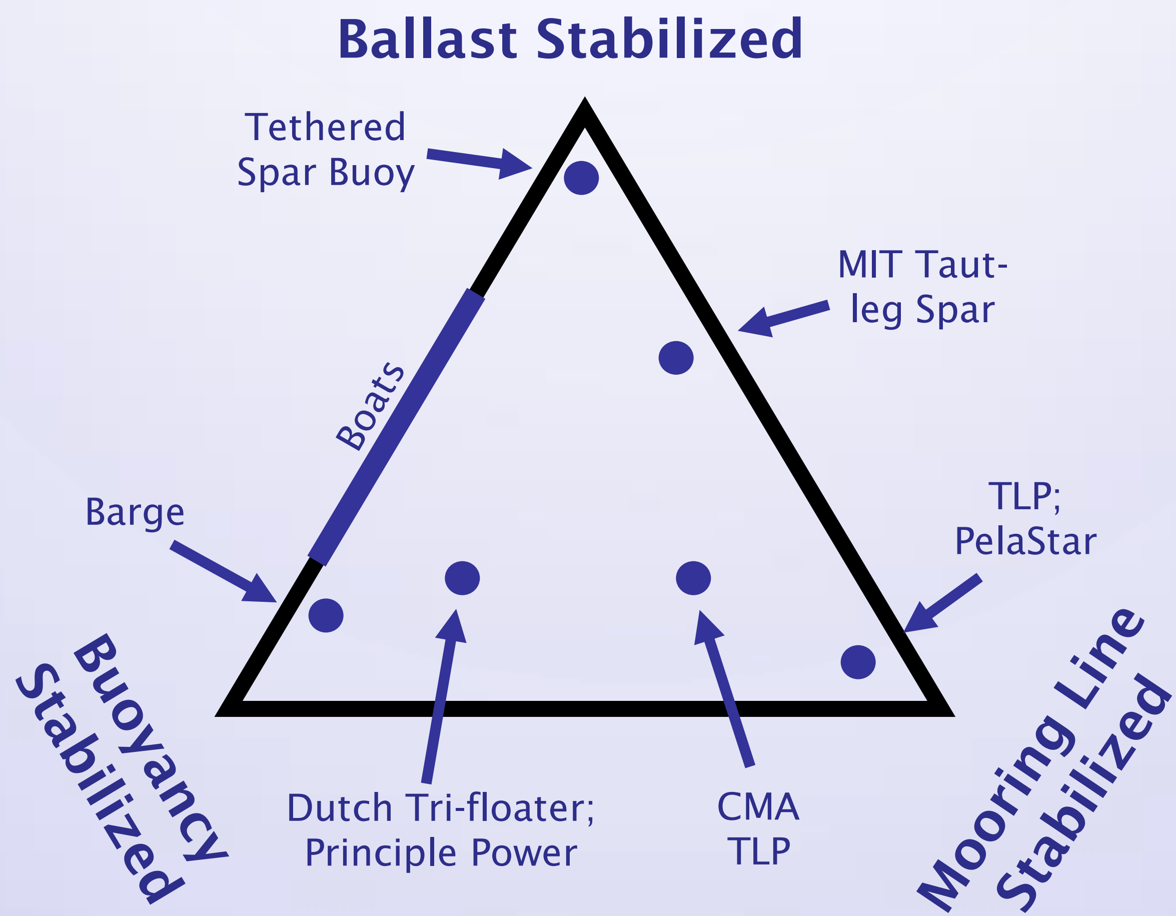
Source: Musial & Ram, NREL, 2010



Dutch Tri-Floater | Barge | Spar Buoy | Tension Leg Platform | Tension Leg Platform with | Sway

Floating Platform Stability Triangle

Source: Butterfield et al., 2005



Statoil Hywind

Turbine rated capacity	2.3 MW
Turbine weight	138 tons
Draft hull	100 m
Nacelle height	65 m
Rotor diameter	82.4 m
Water depth	200 - 220 m
Displacement	5300 m^3
Mooring	3 lines
Diameter at water line	6 m
Diameter of submerged body	8.3 m

Nov 2013: The Crown Estate approved lease for 30MW Hywind project 20-30 km off Scotland

Principle Power - WindFloat 1

Source: Banister, Principle Power, July 2014



- Installed off northern Portugal in Oct 2011; still producing today
- Generated and delivered over 10 GWh of energy to Portuguese grid
- Technical availability: 93%
- Performed through extreme weather events, including waves over 15m
- Energy output consistent with onshore turbine under same wind conditions

Comparison WF-1 and WF-2

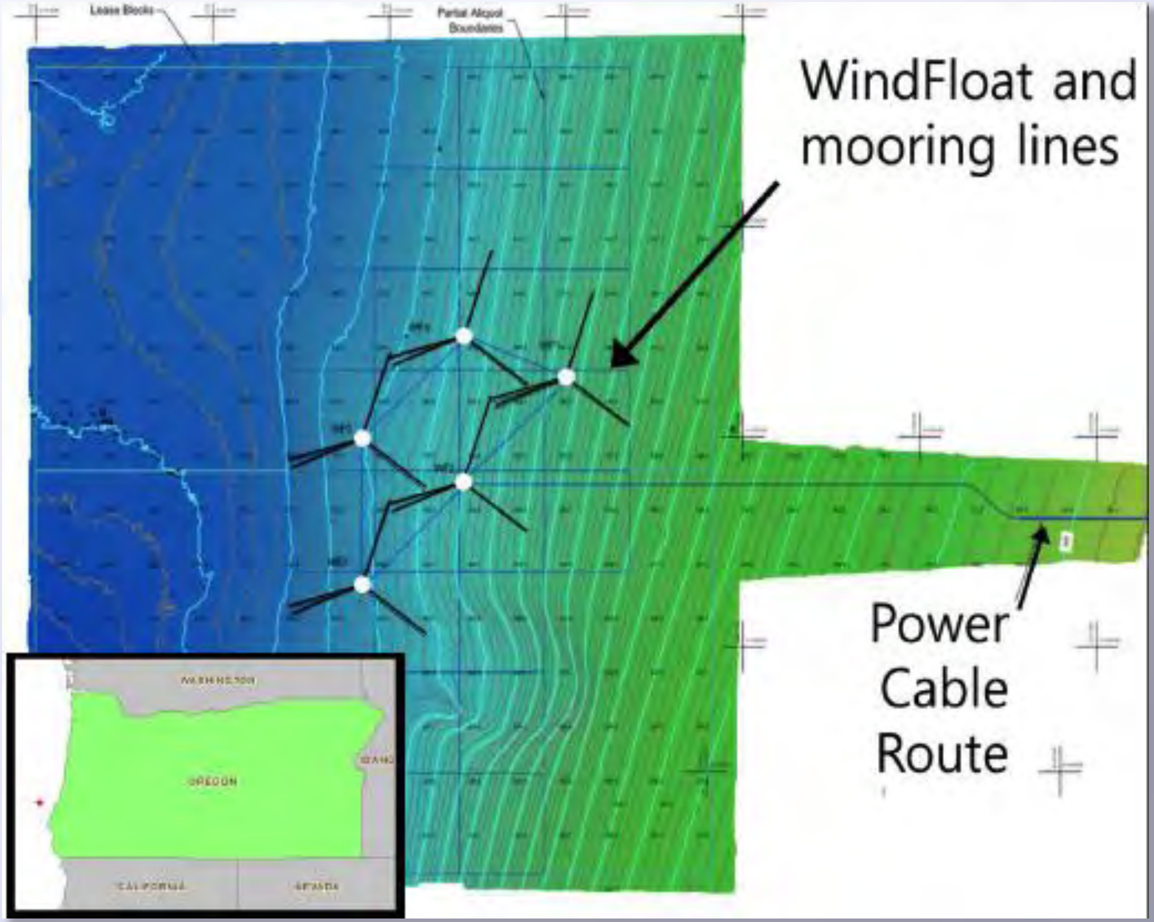
Source: Banister, Principle Power, July 2014

Dimensions	2MW Prototype	6MW
Rotor Diameter	80m	154m
Draft	13.7m	18m
Tower height	56m	88m
Column height	23.2m	27.5m
Column diameter	8.2m	10.5m
Column to column	38m	50m
WEP Length	12m	13.2m
Displacement	2800tonnes	6000tonnes

Principle Power Project Site

Source: Banister, Principle Power, July 2014

- Lease application filed with BOEM on 14 May 2013
- Lease issuance target Q2 2015
- Commissioning target before end 2017
- Approx. 18 miles offshore
- Project will be in about 350+ meters (1,200 ft) of water
- Generally sandy/silly bottom



California Offshore Wind Power Forum 2013

June 11 & 12, 2013
University of California - Davis
Davis, California

The University of California, Davis and the California Energy Commission hosted a two day symposium to explore the future of offshore wind power off the coast of California. The Forum featured four panels of expert speakers discussing regulatory, environmental, technical, and economic challenges and opportunities. Drawing upon experience from overseas, other states, and other industries, they looked at how California can effectively and responsibly proceed to harness the abundant winds off its shores.

The proceedings of the Forum, including presentations are available at: http://cwec.ucdavis.edu/presentation/california-offshore-wind-power-forum/

California Offshore Wind Power Forum Takeaways - General

- Internationally, offshore wind power is growing fast with roughly 5 GW capacity installed, almost all in shallow water.
- The Department of Energy (DOE) and Department of Interior's National Offshore Wind Strategy includes the following goals:
  - 10 GW deployed by 2020 at $0.10 per kWh
  - 54 GW deployed by 2030 at $0.07 per kWh
- First commercial projects in the United States are moving forward on the East Coast. Cape Wind is approaching construction.
- California contains a sizable offshore wind resource which could provide 661 TWh annually.

California Offshore Wind Power Forum Takeaways - Regulatory Issues

- California's regulatory process is complex and lengthy, involving numerous federal, state, and local agencies and a wide array of stakeholders.
- The Bureau of Ocean Energy Management (BOEM), a federal agency, is the lead for offshore leasing in federal waters (in general, more than three nmi beyond shore).
- At the state level, a number of agencies would be involved including the State Lands Commission, the Ocean Protection Council, and Fish and Wildlife.
- As part of their "Smart from the Start" initiative, BOEM facilitates working with state and local agencies by establishing interagency state task forces.
  - Twelve state task forces have been established so far, including Oregon and Hawaii, but not California.
  - To establish a task force, the state governor's office must initiate contact with BOEM.
  - Experience from past efforts with marine protected areas in California can be applied to marine spatial planning today.
- Regulatory and permitting lessons and best practices can be gleaned from Europe and the East Coast.

California Offshore Wind Power Forum Takeaways - Technology Issues

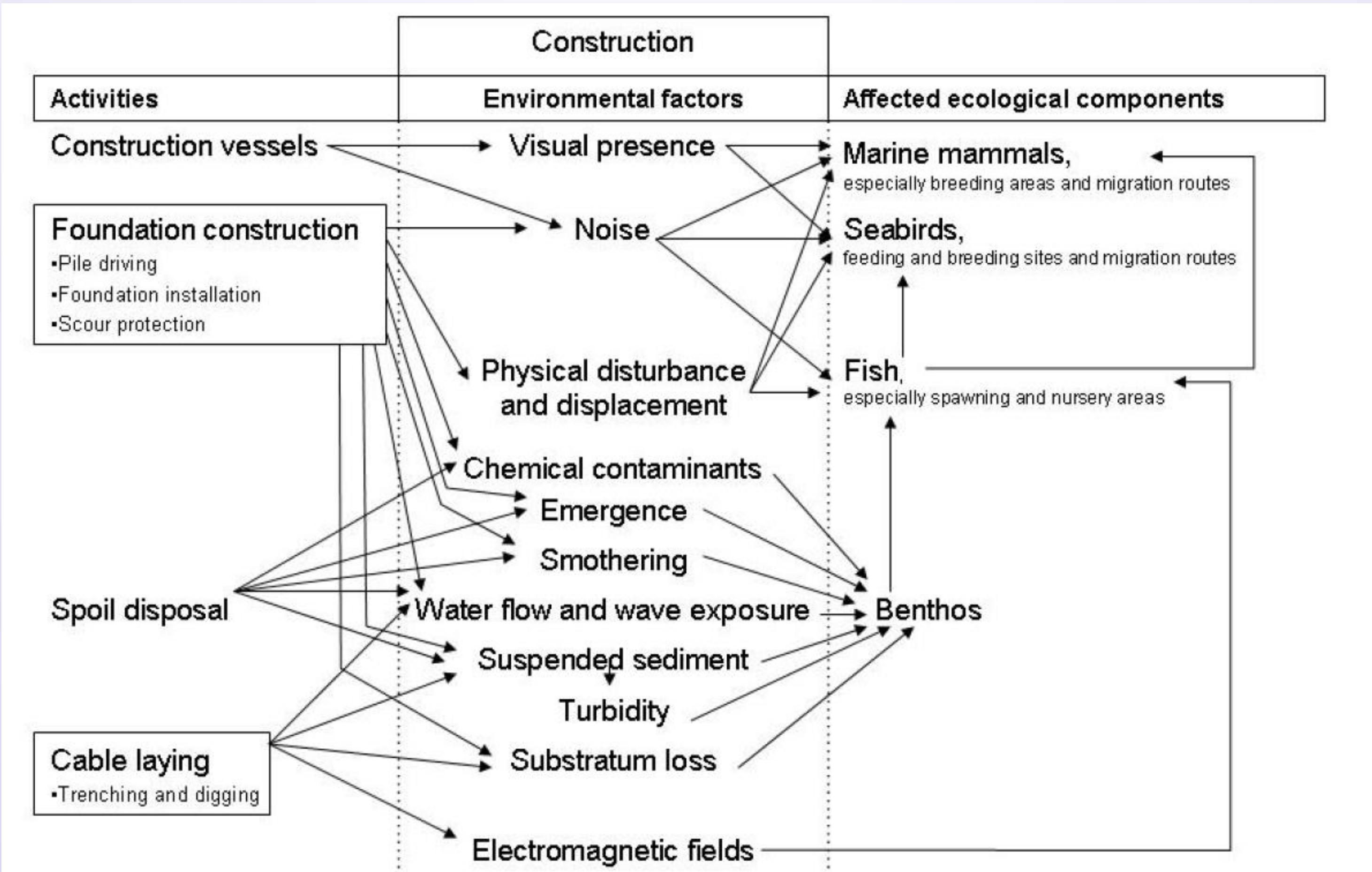
- California's deep waters will require floating platforms for wind turbines. This technology is still in the prototype stage.
- Floating platforms have converged upon three primary configurations.
- Two full-scale wind turbines have been deployed on floating platforms. A number of reduced-scale floating turbines have also been demonstrated.
- Principle Power has received DOE funding toward development of a floating wind power demonstration project off the Oregon coast.

California Offshore Wind Power Forum Takeaways - Environmental Issues

- Environmental baseline data is needed for potential offshore wind energy development areas, including information on coastal processes, birds, fish, marine mammals, noise, and electromagnetic fields.
- Pacific Northwest National Laboratory maintains TETHYS, a database of potential environmental impacts from offshore wind development.
- Studies are ongoing to address information gaps; many opportunities for collaboration.
- California can leverage experience from the state’s earlier efforts with assessing wave energy.

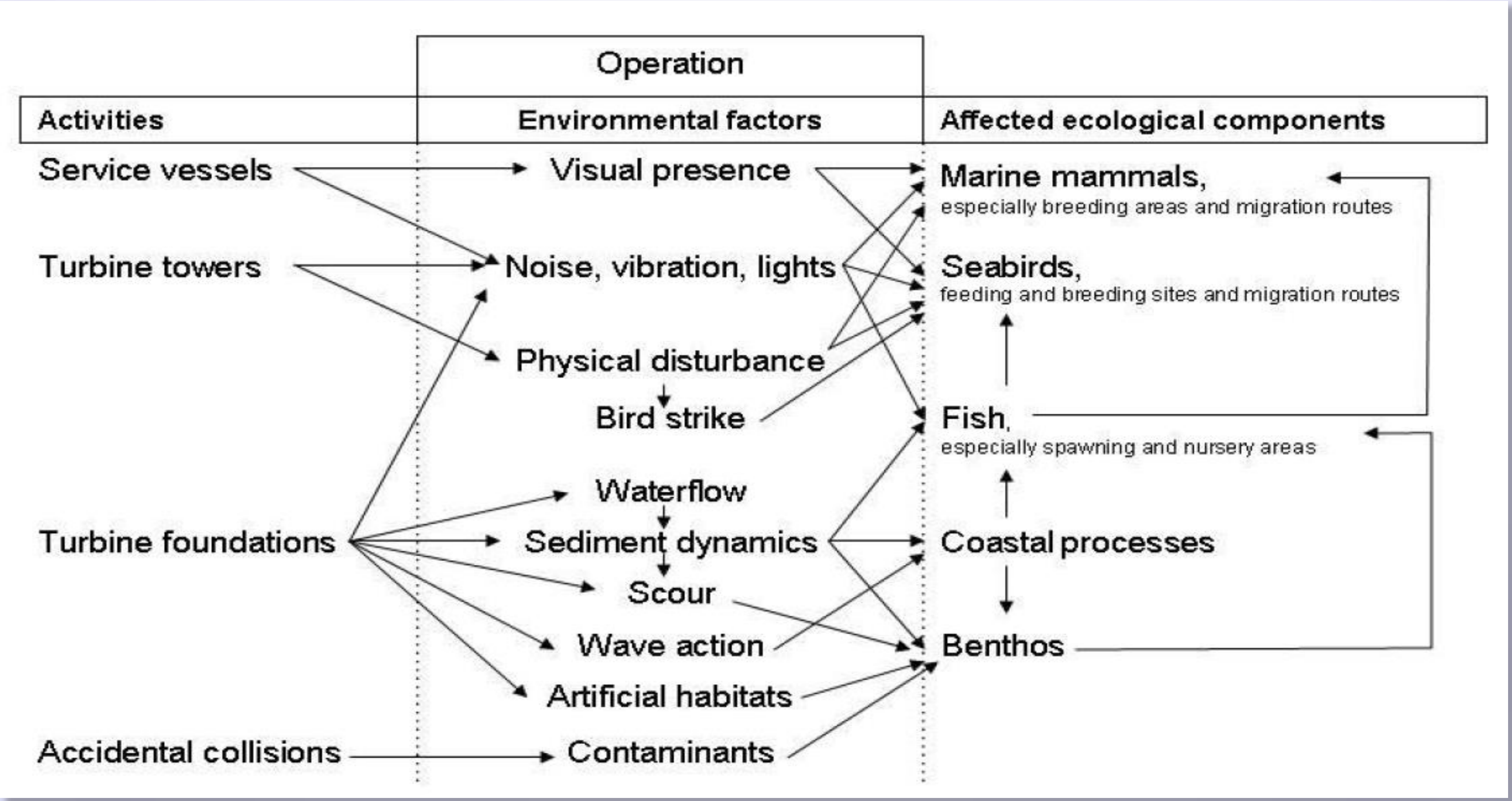
Environmental Impacts: Construction

Source: Van der Wal et al., WindSpeed, 2009



Environmental Impacts: Operation

Source: Van der Wal et al., WindSpeed, 2009



Marine Development Parties in CA

(Selected agencies)

- Bureau of Ocean Energy Management
- California Governor's Office
- California Energy Commission
- California Public Utilities Commission
- California Fish and Wildlife
- U.S. Fish and Wildlife
- National Oceanic and Atmospheric Administration
  - National Marine Fisheries Services
  - National Marine Sanctuaries
  - Office of Ocean and Coastal Resource Management
- California State Lands Commission
- California State Parks
- National Park Service
- U.S. Defense Department
  - Army
  - Navy
  - Air Force
  - Coast Guard
- Ocean Protection Council
- California Coastal Commission
- Federal Energy Regulatory Commission
- County agencies

Final Observations: Offshore Wind

- **Great Opportunity:**
  - Bountiful energy resource
  - Near load centers
  - Benefits from extensive onshore technical and regulatory experience
  - Leverage experience from other industries
    - Oil and gas industry
- **Great Challenge:**
  - Young industry
  - Costs are currently high
  - Lack of established infrastructure
    - Coastal facilities
    - Ships
  - Cost challenges
    - Larger turbines
    - Deep water /floating platforms
    - Maintenance
  - New environmental considerations
  - Complex regulatory process with limited experience

Final Observations: CA Offshore Wind

- **Future of California offshore wind power depends on:**
  - California's Renewables Portfolio Standard beyond 2020: 50% RPS?
  - Willingness of industry to deal with many regulatory hurdles facing offshore renewable power development in California
  - Cost of offshore renewable energy compared to land-based renewables; particularly solar PV

9:00	Introduction and Overview
9:15	Integrated assessment of renewable technology options
10:15	Break
10:30	Assessment of Co-located renewable generation potential
11:00	Assessment of geothermal in under-served regions
11:30	Solar heating and cooling technology analysis
Noon	Lunch
1:15	California off-shore wind technology assessment
1:45	**Technical assessment of small hydro**
2:15	Biomass resources and facilities database update
2:45	Break
3:00	Assessment of sustainability for new/existing biomass energy
3:30	Biomass/MSW gap assessment and tech options for biogas clean-up
4:15	Future research recommendations
4:45	Closing

Technical Assessment of Small Hydro Power Technologies

Technical Assessment of In-conduit Small Hydro Power Technologies

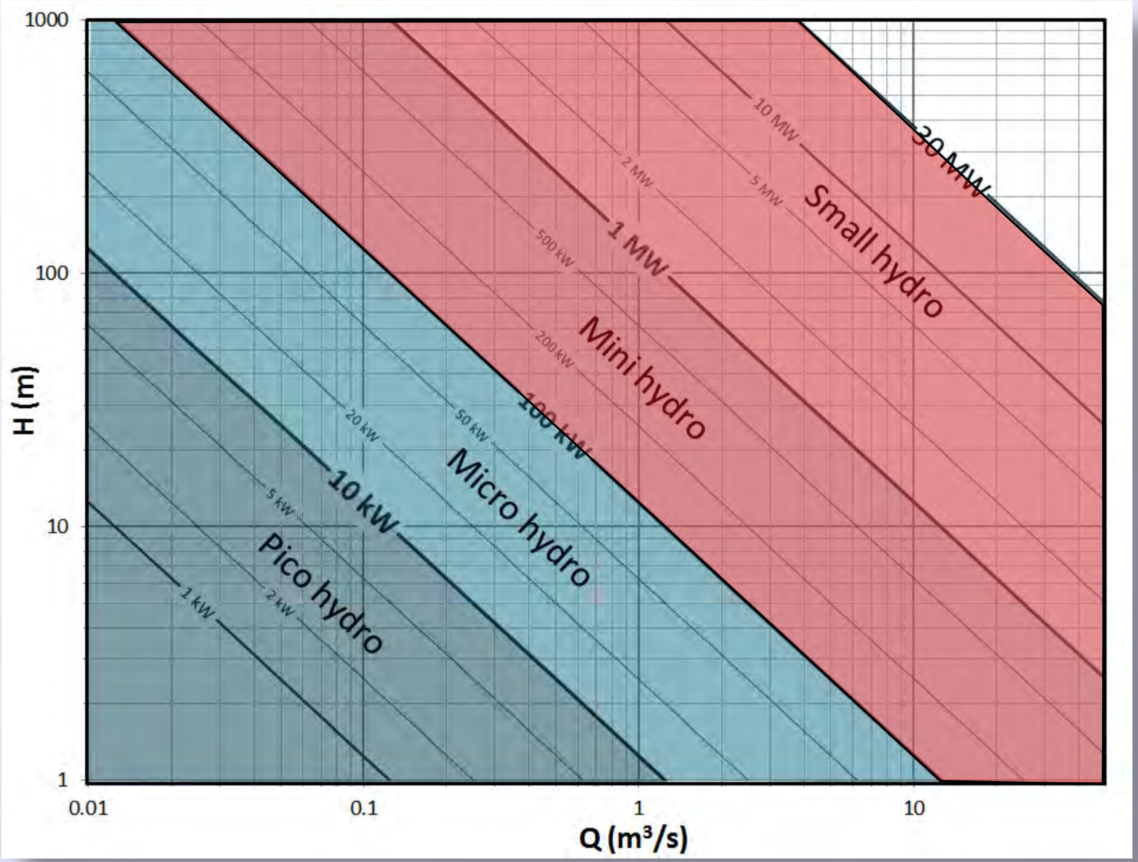
The goal of this study is to investigate and assess available small hydro power generation technologies and associated operating and performance parameters.

Objectives:

- Small Hydro Technology Inventory
- Simulation Needs for Quantitative Evaluation of In-Conduit Small Hydropower
- Evaluation Criteria to Assess Likely Viability and Usefulness of New Generation Technologies
- Status and Challenges of In-Conduit Small Hydro Deployment in California

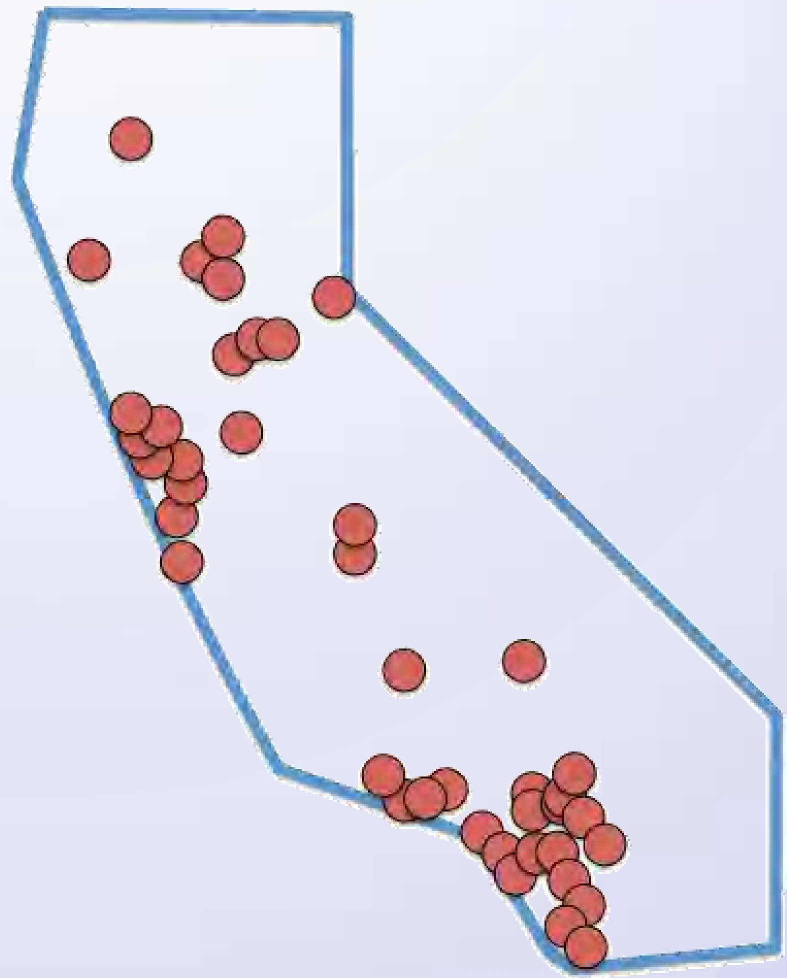
Scope of Small Hydro Technologies

- Small Hydro (100kW to 30 MW)
- In-Conduit focus
- Turbine Technology



Survey

- Sample Size: 181 water agencies
- Responses: 45 water agencies (~25% response rate)
- Statistical accuracy
- Survey provided useful information regarding in-conduit hydropower deployment, simulation needs, incentives, etc.

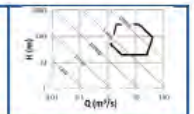


Small Hydro Technology Inventory

- Inventory includes more than 40 small hydropower generation technologies, most newly developed
- The inventory list contains the following entries:
  - Turbine Manufacturers' Name, Location and Website
  - Small icons used to indicate the turbine type
  - A head/flow diagram for each turbine (except hydrokinetic devices), as well as a list of existing projects, if applicable.

IV.1. FRANCIS TURBINES

Manufacturers include: Alstom, Andritz, Canadian Hydro, Canyon Hydro, Cink, Dependable Turbines, Gilkes, Hitachi Power Systems, Mavel, Mecamidi, NorCan, Voith, Wiegert & Bähr



Francis turbines are reaction turbines with a radial inlet and axial discharge. The inlet is typically a spiral casing that directs the flow through a set of guide vanes that can be adjusted to maximize efficiency for different flow rates. Fixed guide vanes can be used to reduce the complexity of manufacture and operation, at the cost of lower efficiency at off-design flow rates. Francis turbines may be oriented with the outlet in a horizontal or vertical direction. Outflow frequently exits through an expanding draft tube which maximizes the pressure difference across the turbine.

Francis turbine in spiral casing with generator

[image: commons.wikimedia.org]

Cut-away showing Francis runner (red) with adjustable guide vanes (yellow)

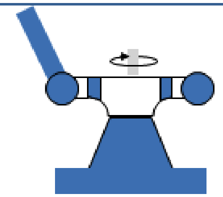
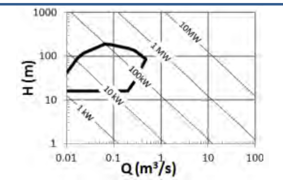
[image: commons.wikimedia.org]

Table 3. Quick reference guide to technologies discussed in this section

Product Name (Company)	Turbine Type	TRL	Site Type	Power (kW)	Activity Level	Installations CA	US	Other
Francis Turbine (various)	Francis	9	P, D, RoR	> 500	Active	✓	✓	✓
Francis Plate Turbine (Small Turbine Partner)	Francis	8	P, D, RoR	500 – 4000	Active			✓
Alden Turbine (EPRI / Alden / Voith)	Francis	5	D, RoR	10,000	Active		✓	
Ultra Low Head Turbine (Nautilus)	Francis	5	RoR	0.5 – 3	Active		✓	✓
Reaction Turbine (Cornell Pump)	PAT	9	P, RoR	1 – 350	Active	✓	✓	✓
Difgen (Zeropex)	PAT	7	P	< 110	Active	✓		✓
Hydrokinetic Energy Recovery Opportunity (Rentricity)	PAT	7	P	15 – 55	Active		✓	

Pump as Turbine

Pumps-as-Turbines

Cornell Pump **Clackamas, OR** http://cornellpump.com/		

Cornell pumps are a common choice for small in-conduit hydro in California as well as other states. The company's primary products are pumps for a variety of applications including municipal water systems. When operated in reverse, the centrifugal pumps are marketed as reaction turbines.

Selected Projects

Cox Avenue, Saratoga, CA (2011) – 110 kW – two PATs

Burbank, CA (2002) – 300 kW – two PATs replacing a pressure release valve at a pumping station

Alameda, CA (1993) – 1,250 kW – six PATs in supply line to a water treatment plant

Planned Projects

Rialto, CA – 310 kW – two PATs on pipeline entering water treatment plant

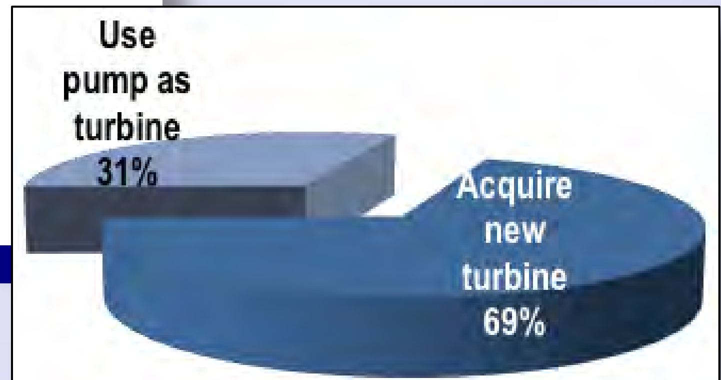
University Mound, San Francisco, CA – 240 kW – three PATs in water delivery pipeline

Difgen

Zeropex

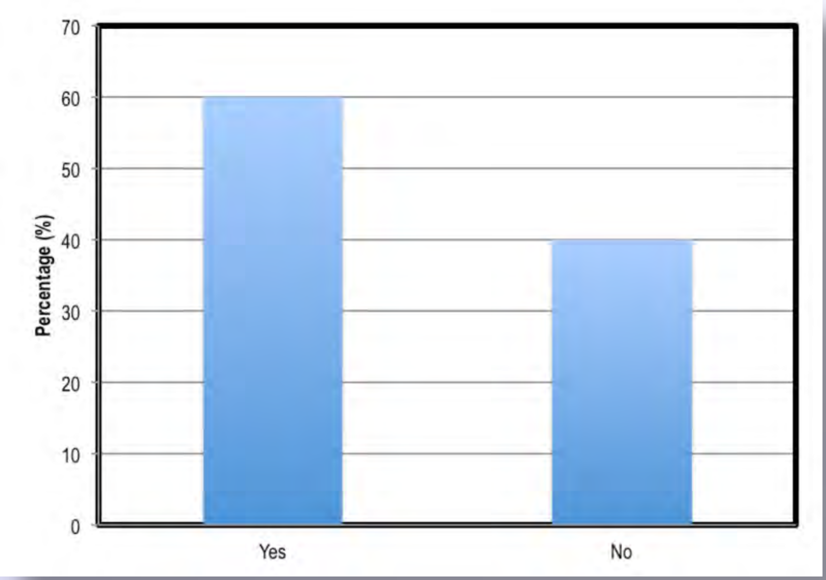
ttp://www.zeropex.com

Surveyed Water Agencies



Simulation Needs for Quantitative Evaluation of In-Conduit Small Hydropower

Do you use any software tools to simulate your water distribution system?



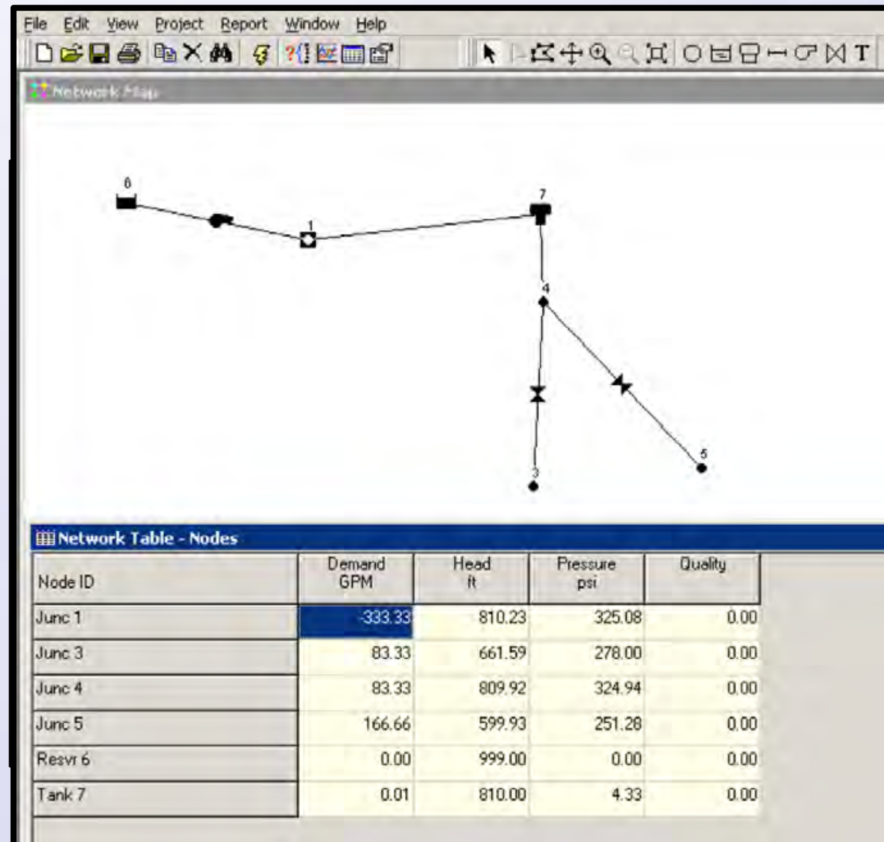
Software Tool	Users (%)	Tool Description
AutoCAD	19	AutoCAD is a 2-D and 3-D computer-aided design (CAD) program that water districts use to draft, design, and simulate their water distribution network systems ("AutoCAD," 2014).
EPANET	22	EPANET is used for mimicking hydraulic simulaton and water quality behavior over a period of time within pressurized pipe networks. It includes components such as reservoirs, pipes, tanks, and valves for simulation of water distribution networks (Rossman, 2000).
Innovyze® InfoWater®	22	Integrated with ArcGIS (geographic information system), Innovyze InfoWater enables water districts to simultaneously perform hydraulic modeling with geospatial analysis of their water distribution networks ("InfoWater Modeling Made Easy: Overview," 2014).
$H_2$0NET®	15	$H_2$0NET is a tool used to design, analyze, and model water distribution networks. In addition to the hydraulic analysis, it can be used to model water quality, and perform both fire flow and energy cost analyses ("H2ONET Modeling Made Easy: Overview," 2014).
$H_2$0Map Water®	15	Similar to InfoWater, H_2OMAP Water in order to accurately perform water distribution network modeling combines both spatial analysis tools and mapping functions ("H2OMAP Water Modeling Made Easy: Overview," 2014).
InfoWorks® CS	4	InfoWorks CS performs hydrological modeling of complete urban water cycle. In addition, it can be used to predict urban flooding and pollution, and model water quality and sediment transport throughout a water distribution network ("InfoWorks CS: Overview," 2014).
SynerGEE® Water	4	Seemingly similar to EPANET, SynerGEE Water is a simulation tool used to model and analyze closed conduit networks. It can model and perform analysis of network elements that include pipes, regulators, pumps, valves, reservoirs, tanks, wells, and boreholes ("SynerGee Water: Advanced Water Distribution Analysis," 2013).
SCADA System	4	Supervisory Control and Data Acquistion (SCADA) is a compute software system that monitors and controls industries such as water and waste control, oil and gas refining and transportation to prevent disasterous events such as leaks on pipelines (Beal).

Simulation Needs for Quantitative Evaluation of In-Conduit Small Hydropower

Simulating Water Distribution Networks

(e.g. as InfoWater, H2ONet, H2OMap, EPANET, etc.)

- EPANET is a free software tool from the EPA, designed to model water distribution networks
- Outputs include flow, head, pressure, velocity, chemical concentration…
- Further developments for in-conduit small hydro simulation needs (ex: Cavitation)



Node ID	Demand GPM	Head ft	Pressure psi	Quality
Junc 1	-333.33	810.23	325.08	0.00
Junc 3	83.33	661.59	278.00	0.00
Junc 4	83.33	809.92	324.94	0.00
Junc 5	166.66	599.93	251.28	0.00
Resvr 6	0.00	999.00	0.00	0.00
Tank 7	0.01	810.00	4.33	0.00

Simulation Needs for Quantitative Evaluation of In-Conduit Small Hydropower

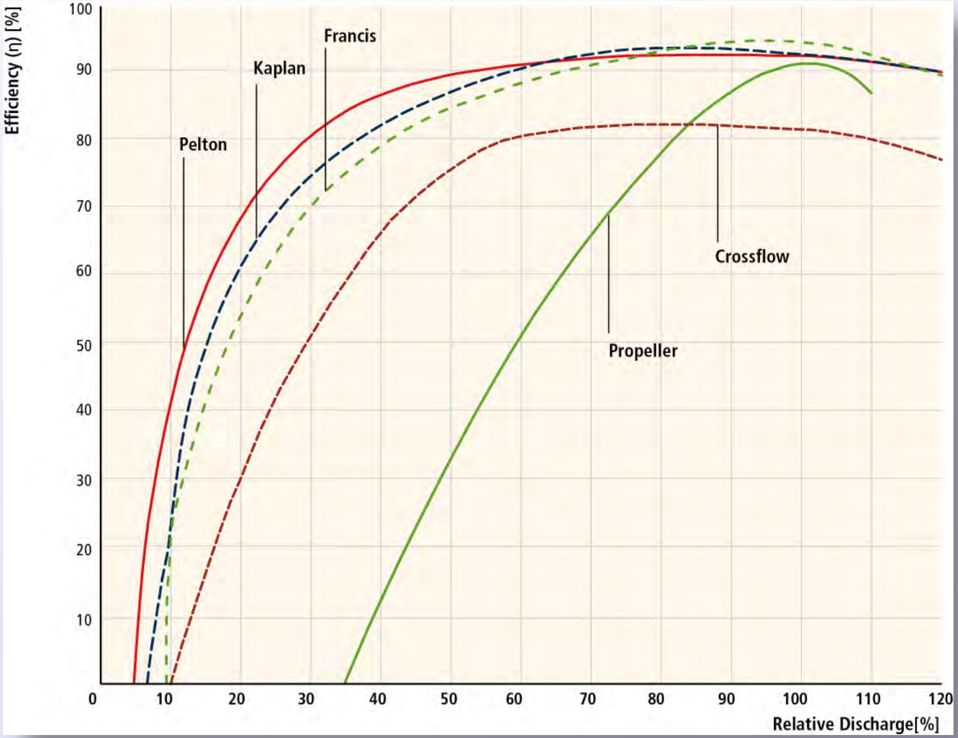
- Cavitation in hydroturbines
  - Nucleation
  - Cavitation in Steady Flow
  - Types of Cavitation
  - Effects of Cavitation
  - Cavitation Modeling
  - Numerical Modeling
  - Choosing a Numerical Model
- Scaling issues
- Noise and material damage
- Effect on water quality

Cavitating vortex in the draft tube of a Francis turbine.

[P.Henry, Institut de Machines Hydrauliques et de Mecanique de Fluides, Ecole Polytechnique Federal de Lausanne, Switzerland, reproduced in Brennan, 1995.]

Turbine Performance Metrics

- Non-dimensional parameters
  1) Efficiency
  2) Cavitation or Thoma number
  3) Specific speed
- Usefulness (Measurements: ASME PTC 18-2011)
  1) Head
  2) Flow (discharge)
  3) Power output
  4) Size
  5) Reaction Ratio



Efficiency curves for common turbine types at partial flow rates.
(Kumar et al., 2011)

Turbine Performance Metrics

Quantities of Interest

$$gH = f_1(\mathrm{bhp}, D, n, \rho, \mu, \varepsilon) \qquad Q = f_2(\mathrm{bhp}, D, n, \rho, \mu, \varepsilon)$$

$$\frac{gH}{n^2 D^2} = g_1\left(\frac{\mathrm{bhp}}{\rho n^3 D^5}, \cancel{\frac{\rho n D^2}{\mu}}, \cancel{\frac{\varepsilon}{D}}\right) \qquad \frac{Q}{nD^3} = g_2\left(\frac{\mathrm{bhp}}{\rho n^3 D^5}, \cancel{\frac{\rho n D^2}{\mu}}, \cancel{\frac{\varepsilon}{D}}\right)$$

$$C_H \approx g_1\left(C_P\right) \qquad C_Q \approx g_2\left(C_P\right)$$

Efficiency and Power Specific Speed

$$\eta = \frac{\mathrm{bhp}}{\rho g Q H} = \eta(C_P) \qquad N'_{sp} = \frac{n\sqrt{\mathrm{bhp}}}{\sqrt{\rho}\left(gH\right)^{5/4}}$$

(F.M. White, Fluid Mechanics, 7th Ed, McGrawHill 2011)

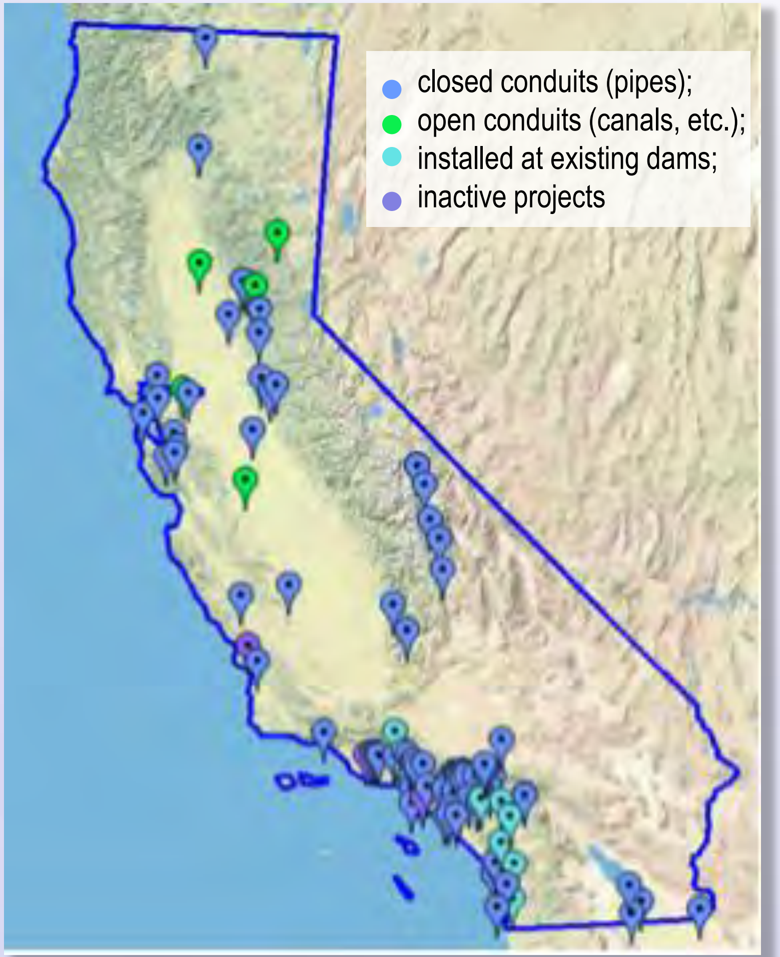
Standards

- Performance
- Implementation
- Water quality
- Testing

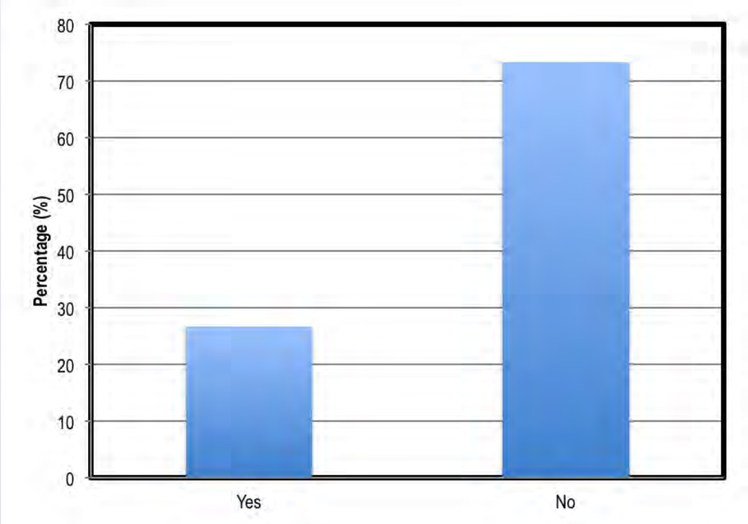
What standards does new hydroelectric equipment need to meet?

Standard	Description
American Water Works Association (AWWA)	The AWWA is a nonprofit association that manages and treats water, and works to find solutions that protect the environment and improve the health of the public. To protect human health, AWWA has set up standards of minimum requirements for materials, equipment, and practices used in water treatment and supply (AWWA).
ASME PTC 18 (Rev. 2011)	ASME PTC 18 is a set standard for manufacturers of hydraulic turbines or pump-turbines of all sizes and types. The standared outlines testing procedures, methods of calculation, methods of measurement, etc. requirements that need to followed by manufactures ("Hydraulic Turbines and Pump-Turbines PTC 18-2011," 2011).
EPA Safe Drinking Water Act (SDWA)	The SDWA is set up under EPA that sets standards to protect potable water and its sources such as rivers, lakes, reservoirs, springs, groud water wells (EPA). NOTE: SDWA does not regulate private wells that serve fewer than 25 individuals.
CA Department of Public Health (CDPH)	The California Department of Public Health enforces the Drinking Water Program, which regulates the public water systems. CDPH is set up to ensure the well being of people in California (CADPH).
NSF 60/NSF 61	If any agency that sells, manufactures, or distributes water must comply with the NSF/ANSI Standards 60 and 61 that set the minimum requirements for chemicals, products, and materials used in treating drinking water supply (NSF:60; NSF:61).
International Electrotechnical Commission (IEC)	IEC is the organization where industries, companies, and governments meet to discuss and develop standards for all electrotechnology (IEC).
Energy Recovery Devices (ERDs)	ERDs are used to recover the energy lost during desalination and other industrial processes ("Energy Recovery Inc Enhances Desalination Industry's Most Efficient, Reliable Energy Recovery Devices," 2011).

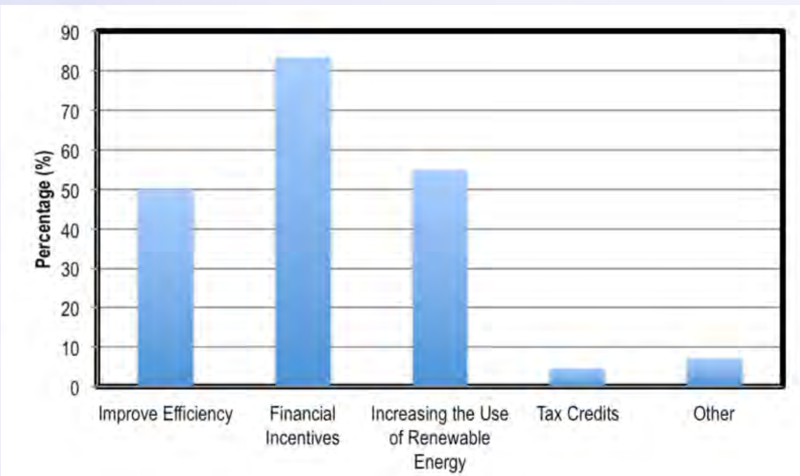
Deployment in California



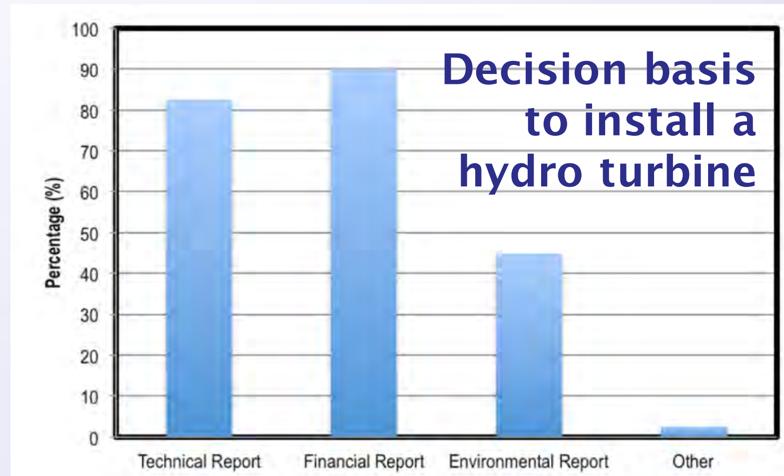
- Map – Data sources: RPS eligible facility list, FERC eLibrary, SGIP quarterly reports, water agencies websites.
- 27% of surveyed water agencies have small hydro turbines currently installed.

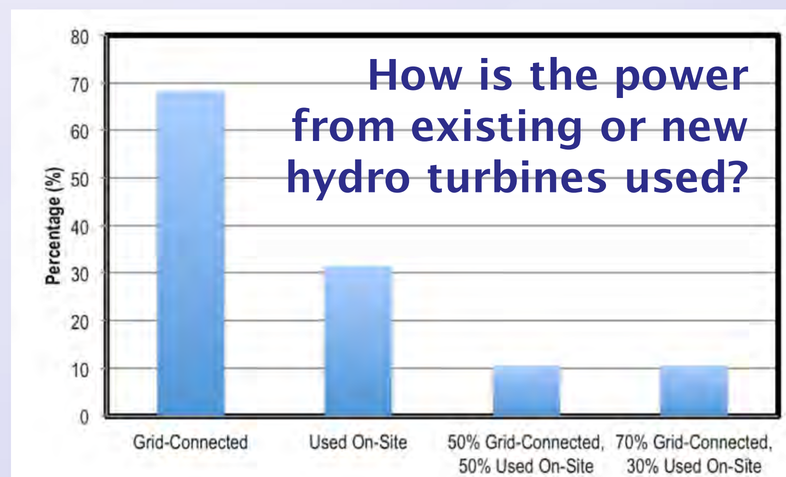


Deployment in California



Factors that prompt a district to install a small hydroturbine on its network





Summary

Findings:

- Hydroturbine Technologies – Goal: reduce cost or complexity for smaller sites (Pumps-as-turbines; Wind-Turbine inspired design)
- Design standardization rather than customization
- Performance scaling issues (cavitation)
- Current deployment of in-conduit small hydro is relatively low (10-25%)

Future Research Needs:

- Independent testing facilities (e.g. improve understanding of performance of PATs)
- Adaptation of existing water distribution network simulation tools needs to accommodate in-conduit small hydro specificity
- Investigation of generators adapted to small-hydro
- Project analysis tool adapted to in-conduit small hydro

9:00	Introduction and Overview
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4:15	Future research recommendations
4:45	Closing

Resources and Facilities Database Update

UC DAVIS
CALIFORNIA BIOMASS COLLABORATIVE

Steve Kaffka
Rob Williams

Biomass Resource Update

- 2014 Update (2012 data) completed in March
- Will produce a 2015 update (2013 data) in Fall
- Estimates Annual Gross and Technical Biomass Resource
  - Bone-dry tons per year (BDT/Y)
  - Electric capacity and energy generation potential (MW, TWh/y)
  - Statewide biogas potential
- Resource Categories: Urban, Agriculture & Food Processing, Forest / Forest Products
- Residues and forest “over growth” – energy crops not modeled here
- Aggregated at County Level

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Gross vs. Technical Resource

- Gross Resource
  - Total mass of residue/forest biomass estimated for each category
- Technical Resource
  - Practical to recover and in a
  - "Sustainable" manner
    - Excludes steep slope & riparian zones in forest
    - Portion of agricultural residue left in field for organic matter in soil, erosion mitigation,
    - etc.
- No economic filter applied
    - Amount that can be recovered economically is less than the technical resource (much less for forest based material)
    - Depends on use and markets

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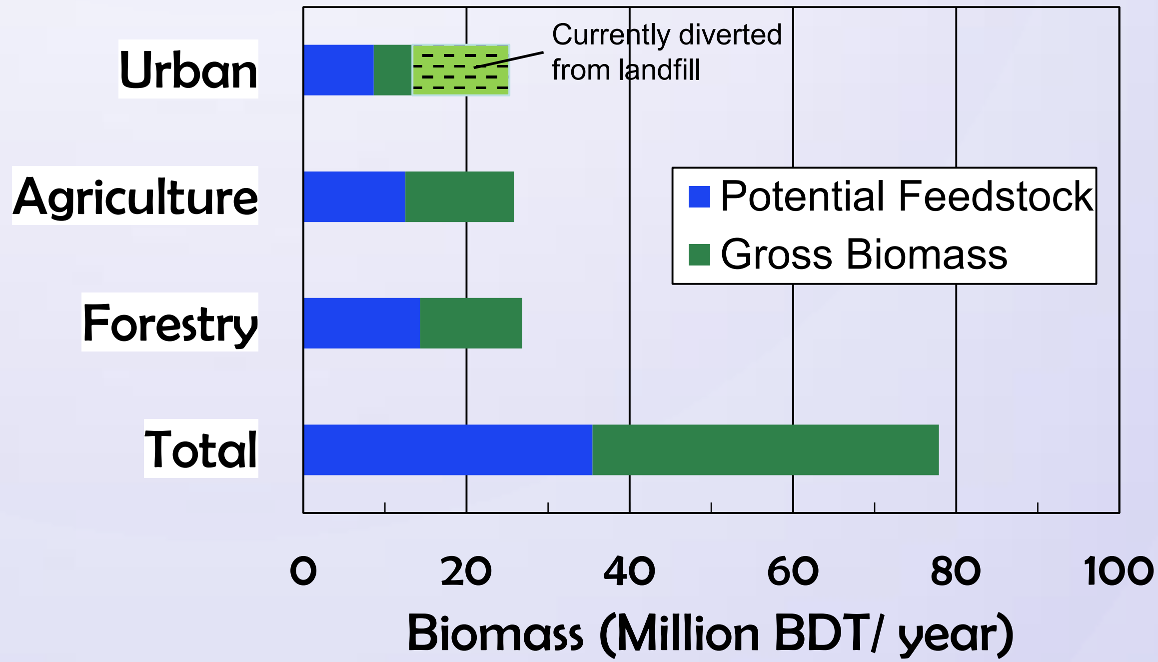
Results

CALIFORNIA BIOMASS COLLABORATIVE

California Biomass Resources

(million dry tons per year)

	Urban	Agriculture	Forestry	Total
Technical Resource	8.6 (from landfill stream)	12.5	14.3	35.4
Gross Resource	12.9 (landfill) 12. 4 (diverted/recycled) 25.3 Total	25.8	26.8	77.9



Williams, R. B., B. M. Jenkins and S. R. Kaffka (2014). An Assessment of Biomass Resources in California, 2012 - DRAFT. CEC PIER Contract 500-11-020, California Biomass Collaborative.

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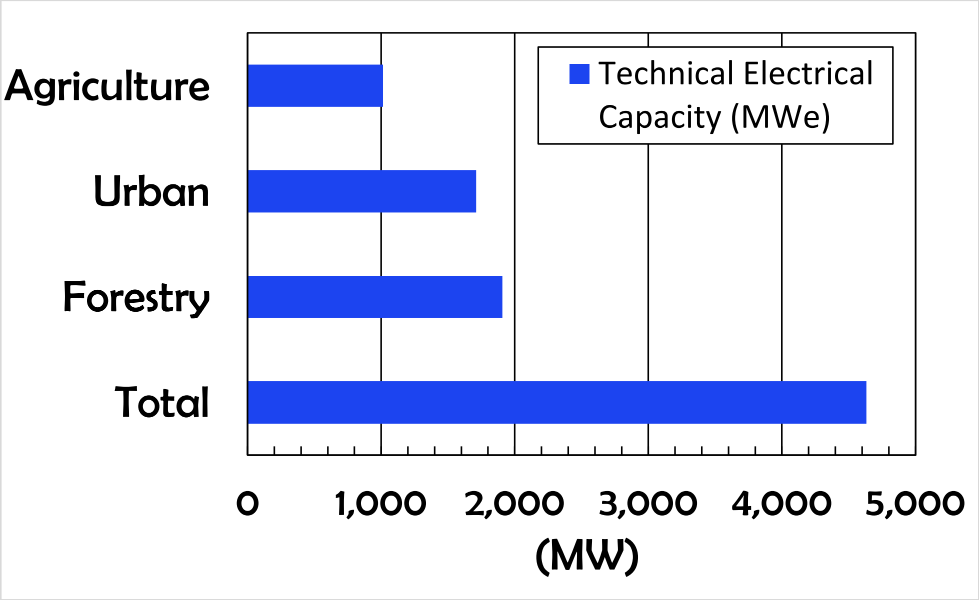
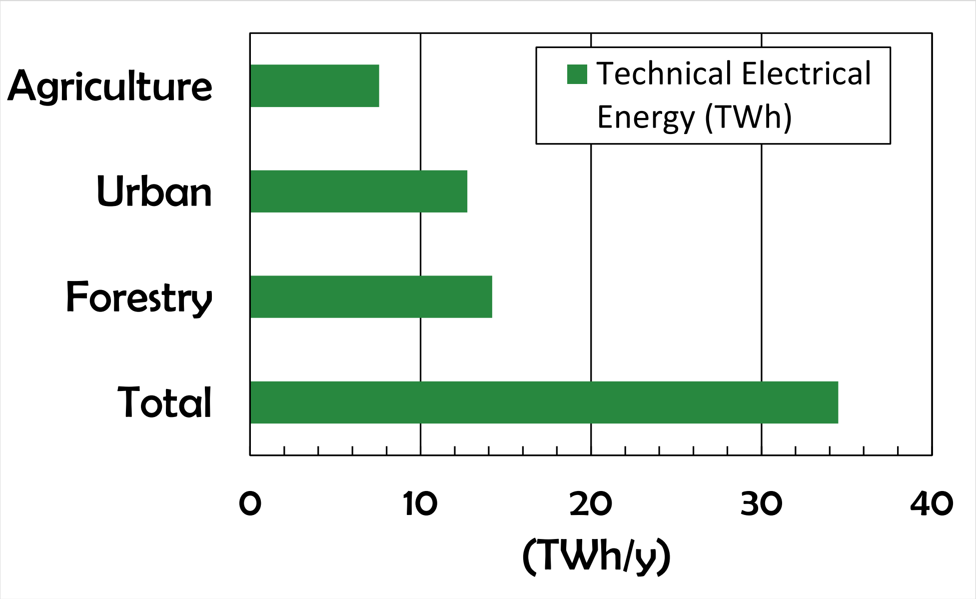
California Biomass Resources
(Technical Electric Energy Potential)





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Statewide Biogas Potential

Feedstock	Biomethane Potential (million m^3 per year)		Technical Energy (PJ, HHV basis)	* Technical Factor Assumption
	Gross	Technical or Recoverable Amount*		
Dairy Manure	943	472	17	50% of manure is recovered
Poultry Manure	174	87	3	50% of manure is recovered
Landfill Gas	2,006	1,505	56	75% recovery of gas produced
Waste Water Treatment Plants	218	196	7	90% recovery of gas produced
Municipal Solid Waste (food & grass / leaves fraction)	519	348	13	67% of feedstock is recovered

Technical Potential Total = 2,600 (million m^3 per year methane)

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Biofuel Potential (all technical resource)

Feedstock	Amount Technically Available	Biomethane Potential (billion cubic feet)	Biofuel Potential (million gge)	PJ (LHV basis)[§]
Agricultural Residue (Lignocellulosic)	5.4 M BDT [a]	-	272 [h]	32.7
Animal Manure	3.4 M BDT [a]	11.8 [a]	102 [i]	12.3
Fats, Oils and Greases	207,000 tons [b]	(assume conversion to biodiesel)	56 [j]	6.7
Forestry and Forest Product Residue	14.2 M BDT [a]	-	710 [h]	85.4
Landfill Gas	106 BCF [a]	53 [f]	457 [i]	55
Municipal Solid Waste (food waste fraction)	0.94 M BDT [c]	10 [g]	86 [i]	10.3
Municipal Solid Waste (lignocellulosic fraction)	7.0 M BDT [d]	-	350 [h]	42.1
Waste Water Treatment Plants	11.8 BCF (gas) [e]	7.7 [k]	66 [i]	7.9
Total			2,100	252.5

* Diesel gallon equivalents can be estimated by multiplying gge by 0.89; **Notes and Sources for Table 58**:M BDT = million bone dry (short) tonsBCF = billion cubic feet a. Williams, R. B., B. M. Jenkins and S. Kaffka (California Biomass Collaborative). 2014. ***An Assessment of Biomass Resources in California, 2012 – DRAFT.*** Contractor Report to the California Energy Commission. PIER Contract 500-11-020. b. From: Wiltsee, G. (1999). Urban Waste Grease Resource Assessment: NREL/SR-570-26141. Appel Consultants, Inc. 11.2 lbs./ca-y FOG and California population of 36.96 million. Biodiesel has ~9% less energy per gallon than petroleum diesel. c. Technical potential assumed to be 67% of amount disposed in landfill (2012). Reference (a) uses a 50% technical recovery factor for MSW stream going to landfill, however it is not unreasonable to assume higher recovery factors as market value of bioenergy product increases or for cases where biomass does not need to be separated before conversion. (waste characterization and disposal amounts are from: http://www.calrecycle.ca.gov/Publications/General/2009023.pdf) d. 67% of mixed paper, woody and green waste and other non-food organics disposed in landfill (2012). Note (c) discusses rational for using a higher technical recovery factor than that assumed for MSW in reference (a). (waste characterization and disposal amounts are from: http://www.calrecycle.ca.gov/Publications/General/2009023.pdf)
e. From EPA Region 9; Database for Waste Treatment Plants f. Assumes 50% methane in gas g. Assumes VS/TS= 0.83 and biomethane potential of 0.29g CH4/g VS h. Using 50 gge per dry ton (75 gallons EtOH per dry ton) yield. See, for example: Anex, R. P., et al. (2010). Techno-economic comparison of biomass-to-transportation fuels via pyrolysis, gasification, and biochemical pathways. [Article]. *Fuel, 89*, S29-S35. doi: 10.1016/j.fuel.2010.07.015
i. ~116 ft^3 methane is equivalent to 1 gge (983 Btu/scf methane and 114,000 Btu/gallon gasoline, lower heating value basis) j. 7.5 lbs FOG/ gallon biodiesel. Biodiesel has ~9% less energy per gallon than petroleum diesel, gives 50 M gallons diesel equivalent. 1 dge = 1.12 gge
Compiled by Rob Williams, University of California, Davis. April 2014 (revised 19 May 2014)

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Methods and Sources – Urban Residues

- Uses Disposal Reporting System Database for MSW (CalRecycle)
- Landfill stream waste characterization (Cascadia – 2008) (about 60% mass of waste stream is/was biomass)
- 2012 landfill disposal amount: Gross Resource
- Technical Recovery Factor: 0.67 (for biomass material in current landfill disposal stream)
- Energy content for each component of waste stream from literature (MJ/kg)

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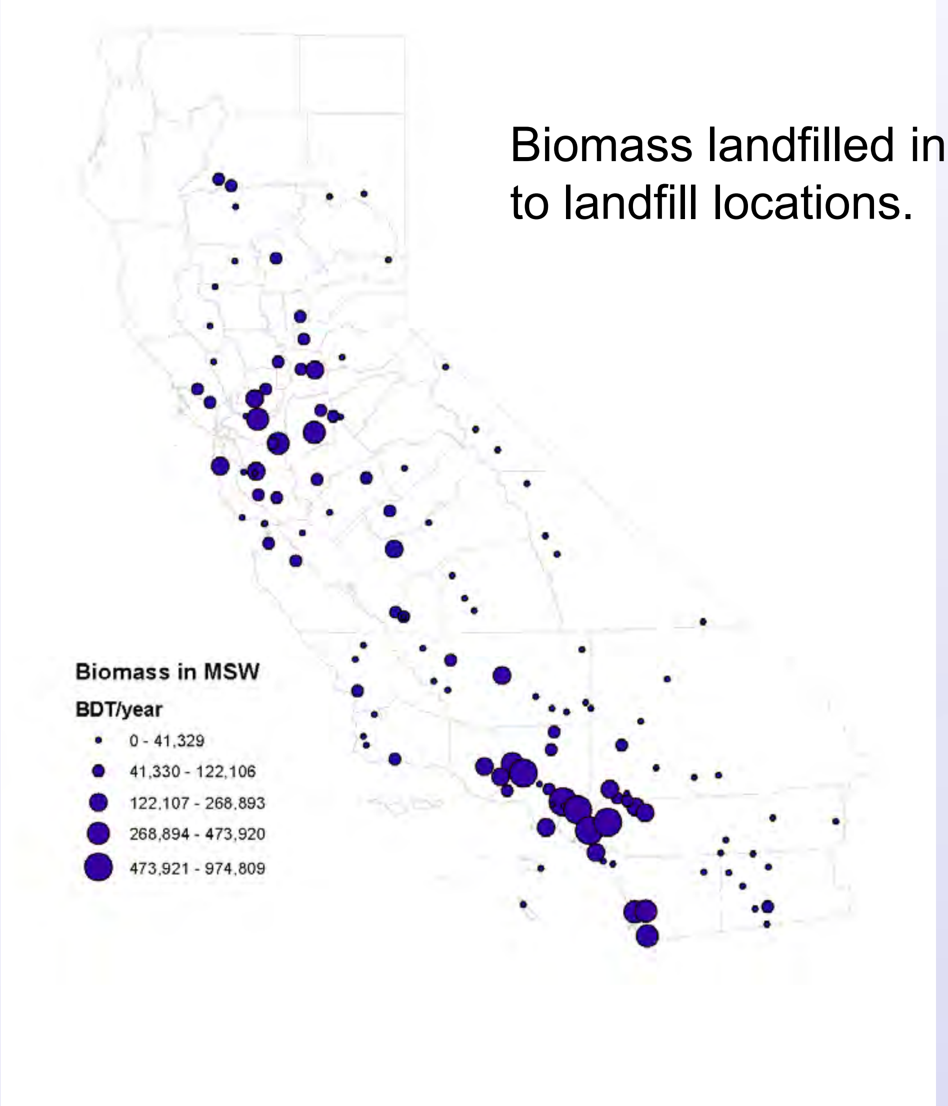
Solid Waste Landfill Stream: Components and Energy Table (MSW Gross Resource)

	Landfilled[a] (million ton -as is)	% of Total	Ash[b] (% wb)	Ash (million ton y^{-1})	HHV[b] (MJ/kg, ar)	HHV contribution to composite stream (MJ kg^{-1} as received)	Moisture[b] (%wb)	Landfilled (million ton dry)	HHV (MJ/kg, dry)	Primary Energy by Component (EJ)[c]	Primary Energy by Component (%)	Electricity Potential[d] (MWe)	(GWh y^{-1})
Paper/Cardboard	5.1	16.4	5.3	0.3	16	2.63	10	4.6	17.8	0.074	24	467	4,089
Food	4.5	14.7	5.0	0.2	4.2	0.62	70	1.4	14.0	0.017	6	155	1,361
C&D Lumber	4.2	13.8	5.0	0.2	17	2.34	12	3.7	19.3	0.066	22	416	3,641
Prunings, trimmings, branches, stumps and green ADC [e]	2.6	8.3	3.6	0.09	11.4	0.95	40	1.5	19.0	0.027	9	169	1,481
Other Organics	1.3	4.1	10.0	0.1	8.5	0.35	4	1.2	8.9	0.010	3	62	540
Leaves and Grass	1.1	3.6	4.0	0.0	6	0.22	60	0.4	15.0	0.006	2	27	240
Biomass Components of MSW Total [e]	**18.8**	**60.9**		**1.0**		**7.1**		**12.9**		**0.20**	**66**	**1296**	**11,352**
All non-Film Plastic	1.8	5.9	2.0	0.04	22	1.29	0.2	1.8	22.0	0.036	12	230	2,015
Film Plastic	1.0	3.2	3.0	0.03	45	1.45	0.2	1.0	45.1	0.041	14	258	2,260
Textiles	1.6	5.1	7.0	0.11	17.4	0.89	10	1.4	19.3	0.025	8	158	1,388
Non-Renewable Carbon Compounds Total	**4.4**	**14.2**		**0.18**		**3.64**		**4.2**		**0.10**	**34**	**646**	**5,663**
Other C&D	4.3	13.9	100	4.3	0	0		4.3					
Metal	1.3	4.4	100	1.3	0	0		1.3					
Other Mixed and Mineralized and ADC [e]	1.6	5.3	100	1.6	0	0		1.6					
Glass	0.4	1.3	100	0.4	0	0		0.4					
Mineral Total	**7.7**	**24.8**		**7.7**		**0.0**		**7.7**		**0**	**0**	**0**	**0**
Totals [e]	**30.9**	**100**		**8.8**		**10.74**	**20**	**24.8**	**13.4**	**0.301**	**100**	**1942**	**17,015**

a) California waste stream composite data (http://www.calrecycle.ca.gov/Publications/Detail.aspx?PublicationID=1346),
& California Solid Waste Generation and Diversion (http://www.calrecycle.ca.gov/LGCentral/GoalMeasure/DisposalRate/Graphs/Disposal.htm) Accessed April, 2013
b) Adapted from Tchobanalglous, G., Theisen, H. and Vigil, S.(1993),"Integrated Solid Waste Management", Chapter 4, McGraw-Hill, New York
& Themelis, N. J., Kim, Y. H., and Brady, M. H. (2002). "Energy recovery from New York City municipal solid wastes." Waste Management & Research, 20(3), 223-233.
c) EJ = 10^18 J (exajoule)) EJ = 10^18 J (exajoule) and is approximately equal to 1 Quad (1 Q = 1.055 EJ)
d) Electricity generation calculations assume thermal conversion means for low moisture stream (paper/cardboard, other organics, C&D Lumber, all plastics and textiles) and biological means (anaerobic digestion) for the high moisture components (food and green waste). Energy efficiency of conversion of matter to electricity by thermal
means is assumed to be 20%. Biomethane potentials of 0.29 and 0.14 g CH4/g VS for food and leaves/grass mixure respectively are assumed for biogas production which is converted at 30% thermal efficiency in reciprocating engines. Capacity factor of 1 is used.
e) Note: updated to show 2012 disposal amount of 29.3 million tons + 1.6 Mtons of green ADC.- http://www.ciwmb.ca.gov/lgcentral/DRS/Reports/Statewide/ADCMatlTyp.asp

MSW resource distribution

Biomass landfilled in 2012 mapped to landfill locations.



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Methods and Sources – Urban Residues: Landfill and Wastewater Treatment Biogas

- Landfill gas production is estimated based on existing waste-in-place (WIP) using a first order waste decay model (similar to USEPA LandGEM)
  - Gross Resource: gas production from annual disposal since 1970 or 1.2 billion tons WIP (some data show1.4 billion tons WIP since 1940)
  - Technical recovery factor = 0.75
- Wastewater Treatment Biogas
  - Based on average daily flow to facilities with digesters
    - Flow data from Greg Kester, California Association of Sanitation Agencies (CASA)
  - 1.15 cubic feet biogas / 100 gallons wastewater inflow (a USEPA factor)
  - Technical recovery factor = 0.90 (maybe too conservative)

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Methods and Sources

– Agricultural Residues

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Methods and Sources – Agricultural Residues

- Crop residues
  - Straw, stover, orchard & vineyard prunings, etc.
- Animal manures
- Food & fiber processing residue
  - Primarily nut shells and hulls
  - Meat processing, other pits and hulls

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Methods: Crop Residues

- Acres planted and harvested data from the National Agricultural Statistical Service (NASS) for over 300 crop types
  - Data based on County Ag. Commissioners crop reports
- Multiply Residue Yield Factors (BDT/acre) times acres for each crop type for Gross Resource
- Technical availability factor applied to obtain Technical Resource
  - Ranged from zero (veg., hay and silage crops) to 0.7 for some orchard/vineyard crops

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Methods: Food and Fiber Processing Residues

- Apply residue yield factors based on food/fiber production amount (rather than acres harvested)
  - ie., Almond Shell yield factor =0.6 lbs./lb. almond meat (gross resource)
- Technical yield factors generally 80% for this class

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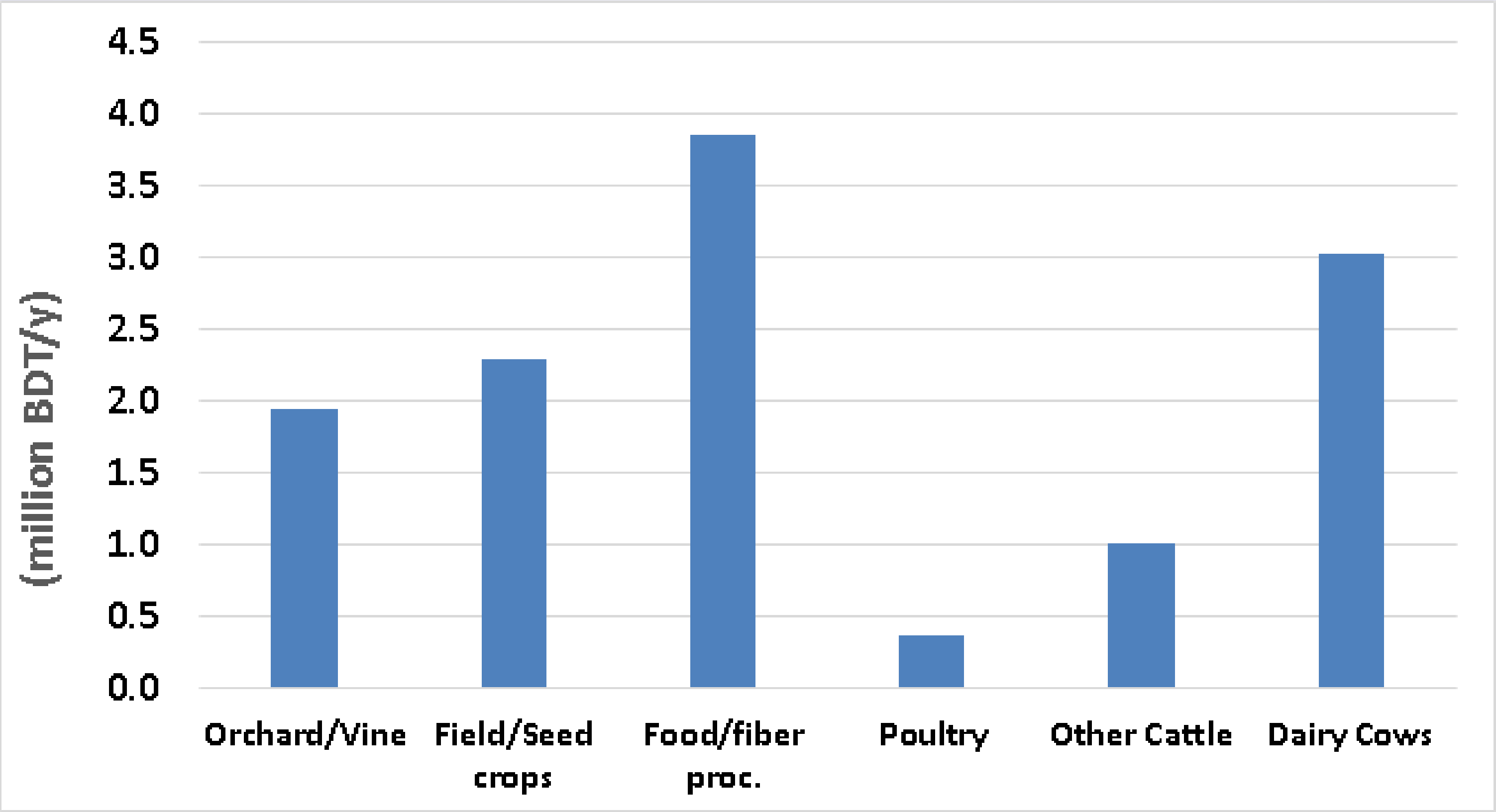
Methods: Animal Manures

- Daily animal manure production and number of animals used to determine gross resource
  - ASAE D384.2 MAR2005 (R2010), Manure Production Characteristics (ASABE).
- Technical recovery factors ranged from 0.2 (beef and other cattle) to 0.5 (dairy and poultry) [dairy/poultry are conservative]

Animal type	Number in California Inventory	Total Wet Manure (lb/animal-day)	Moisture Content (% wb)	Total Solids (TS)			Volatile Solids (VS)	
				(lb/animal-day)	(lb/animal-year)	Statewide (BDT/y)	(lb/animal-day)	(lb/animal-year)
Dairy Cows - Lactating & Dry	1,779,710	140	87	18.7	6,807	6,057,465	15.83	5,778
Beef Cows	620,000	125	88	15.0	5,475	1,697,250	13.00	4,745
Other Cattle (cow replacements & heifers)	3,054,680	50	88	6.0	2,190	3,344,875	5.00	1,825
Swine -growing/finishing	105,000	10	91	1.0	365	19,163	0.85	310
Poultry (Layer Chickens)	19,717,000	0.20	75	0.05	17.9	176,319	0.04	13
Poultry (Broiler Chickens)	37,978,429	0.22	74	0.06	21.3	404,312	0.04	16
Poultry (Turkeys)	5,839,465	0.58	74	0.15	55	160,256	0.12	44
Total	69,094,284					11,860,000		

Agricultural Residues, Technical Resource

- Distribution by category – 12.5 million dry tons per year



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Methods and Sources
– Forest & Forest Product Residues

- Using same forest biomass resource data used in all previous CBC Resource Updates
  - 2005 CDFFP Fire and Resource Assessment Program (FRAP)*
  - Inventory of non merchantable forest biomass and shrubland with 70 or 100 year turn-over assumptions (1/70, 1/100 of inventory available annually – Gross Resource)
  - Technical Resource
    - Excludes steep slope & riparian zones
    - Wilderness and National Park areas
    - Other administrative or regulatory constraints

*Rosenberg, M., J. Spero, and D. Cromwell, (2005). *Biomass potentials from California forest and shrublands including fuel reduction potentials to lessen wildfire threat; Draft PIER Consultant Report, Contract 500-04-004*. California Department of Forestry and Fire Protection

Methods and Sources – Energy Generation Potential

- Relatively dry material is assumed to be converted via thermal means (combustion / gasification)
  - Overall conversion efficiency of 20% (HHV basis) is assumed (electric energy / feedstock energy)
- Typically wet or moist feedstocks (animal manures, food and some green waste components) are assumed converted via anaerobic digestion
  - Biomethane potential and/or volatile solids content are used from literature sources for biogas production
  - Biogas converted to electricity at 30% (HHV) efficiency

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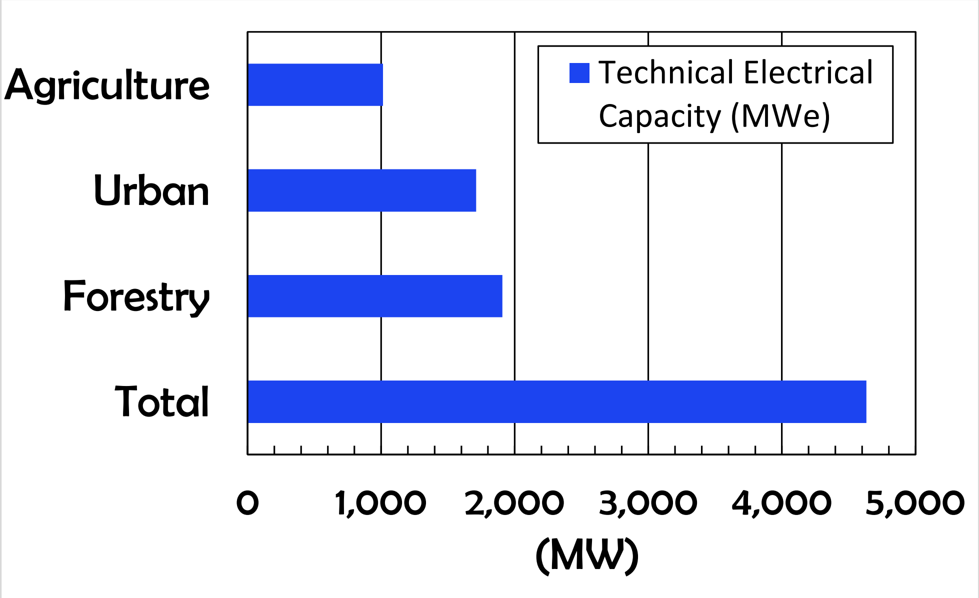
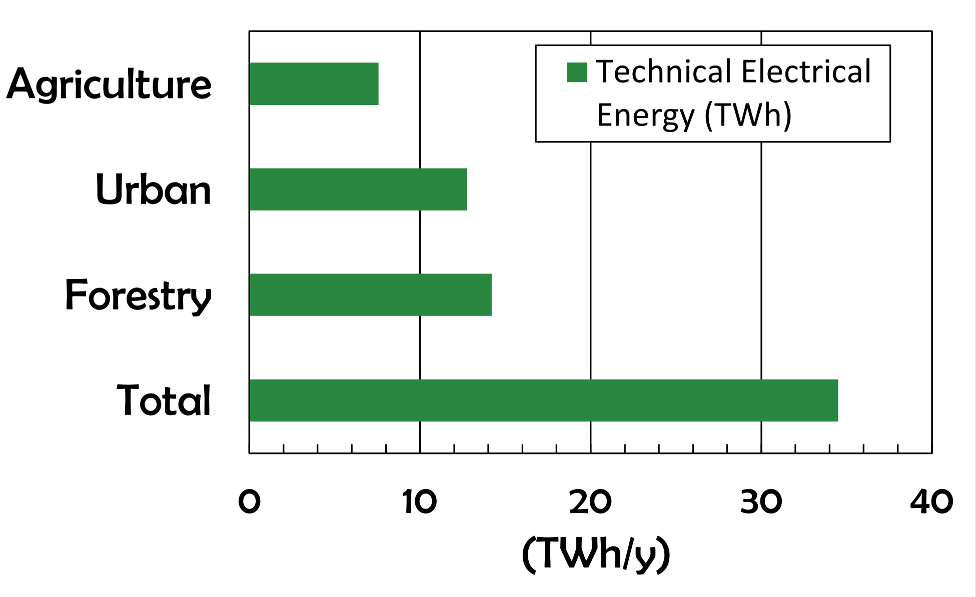
California Biomass Resources
(Electric Energy Potential)





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Bioenergy Facilities Database

- May 2013 is latest update
  - Will update again in Fall
- Facility Types Listed:
  - Solid-fuel power plants (SolidFuel)
  - Landfill gas projects (LFGProjects)
  - Waste water treatment plants w/ anaerobic digesters (WWTP-AD)
  - Farm based digesters (Farm-AD)
  - Food processors & Urban anaerobic digestion (FoodProcess&Urban-AD)
  - Biofuels
- http://biomass.ucdavis.edu/tools/california-biomass-facilities-reporting-system/

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Bioenergy Facilities Database

Primary Data Sources

Category	Foundation dataset
SolidFuel	Woody Biomass Utilization, UC Berkeley, California , Sierra Nevada Conservancy (community scale bioenergy updates)
LFGProjects	Scott Walker, CalRecycle and Solid Waste Information System (SWIS), US EPA, Landfill Methane Outreach Program (LMOP)
WWTP-AD	U.S. Environmental Protection Agency, Region 9
Farm-AD	California Air Resources Board (CARB), US EPA, AgSTAR Program
FoodProcess&Urban-AD	Ricardo Amon, et al. CBC 2011, Jacques Franco, CalRecycle
Biofuels	Renewable Fuels Association, Industry ethanol facilities National Biodiesel Board, biodiesel facilities

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CGEC

Bioenergy Facilities Database

			Net (MW)	Facilities
Biopower	Solid Fuel (woody& ag.)		574.6	27
	LFG Projects		371.3	79
	WWTP Facilities		87.8	56
	Farm AD		3.8	11
	FoodProcess/Urban AD		0.7	2
	Totals		1038	175
	Solid Fuel (MSW)		63	3

		Direct-use (MMscfd)	LNG/CNG (gpd)	Facilities
Biogas: Direct-use CNG/LNG	LFG Projects	24.7		11
	LFG Projects		18,000	2
	WWTP Facilities	26.8		3
	Farm AD		Capacity ??	1
	FoodProcess/Urban AD	20.4		7
	FoodProcess/Urban AD		Capacity ??	1
	Total			25

		(MGY)	Facilities
Biofuels	EtOH	179	4
	Biodiesel	62.1	13
	Totals	241.1	17

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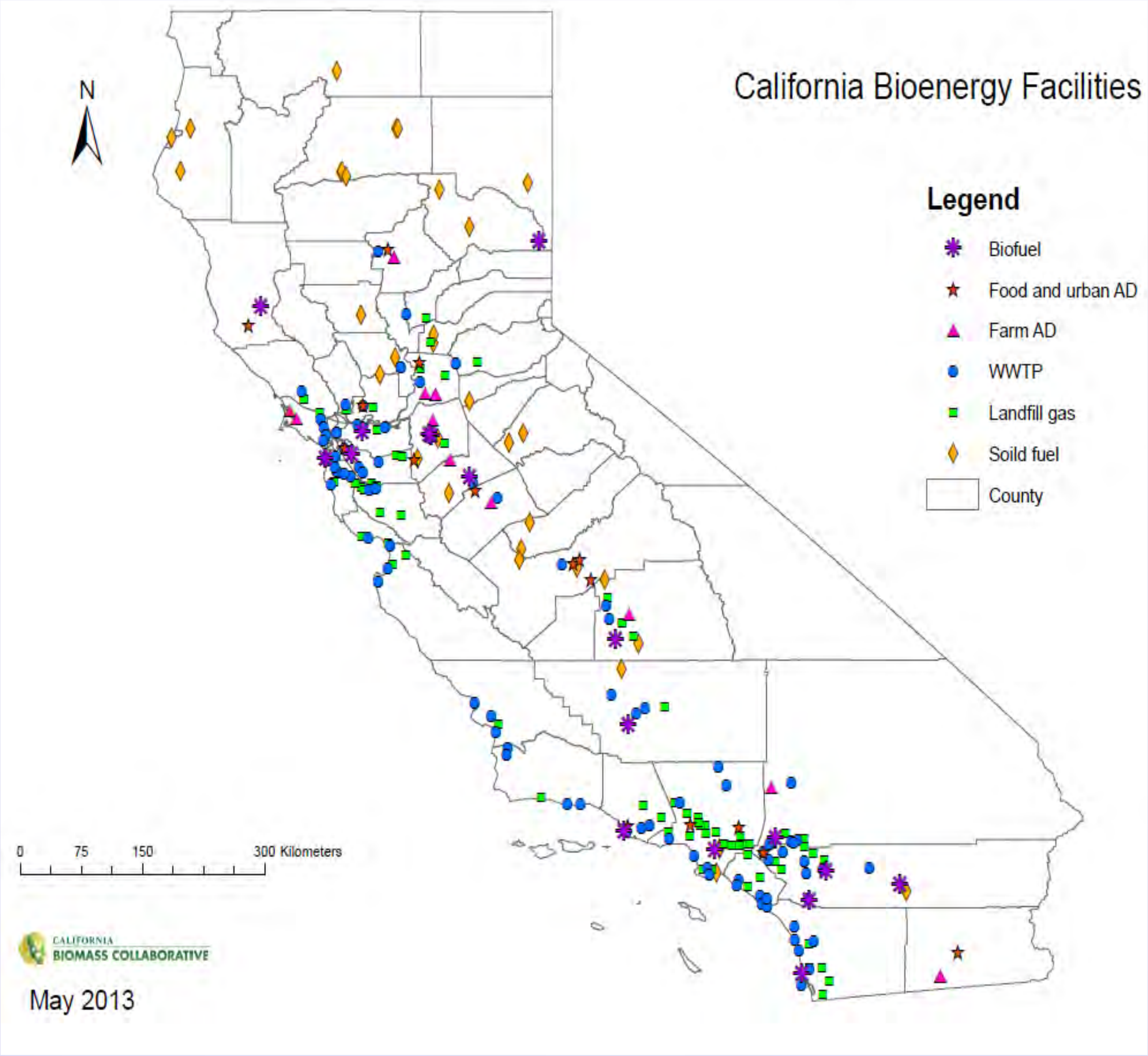
Bioenergy Facilities Database



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Assessment of Sustainability for Existing/New Biomass

UC DAVIS CALIFORNIA BIOMASS COLLABORATIVE

Steve Kaffka
Rob Williams

Biomass-Task 4

Contract #500-11-020

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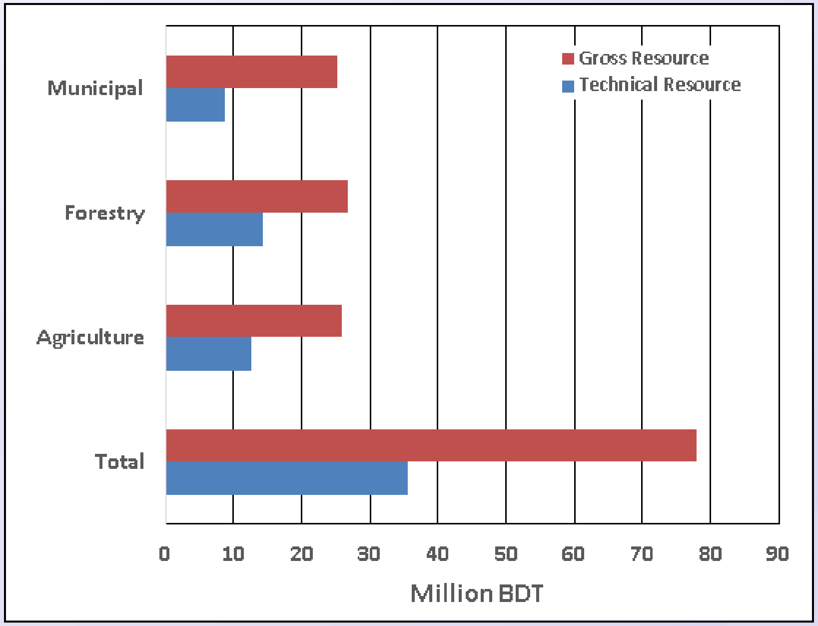
California Renewable Energy Center

California is biomass –rich: there are large amounts of biomass from urban, forest and agricultural sectors.

Resources and generation potential from biomass in California, 2012

Category	Units	Agriculture	Forestry	Municipal Wastes	Total
Gross Resource	Million BDT/y	25.8	27	25	**78**
Technical Resource	Million BDT/y	12.5	14.3	8.6	**35**
Gross Electrical Capacity	MWe	2440	3580	3860	**9,880**
Technical Electrical Capacity	MWe	1015	1907	1712	**4,630**
Gross Electrical Energy	TWh	16	27	29	**71**
Technical Electrical Energy	TWh	8	14	13	**35**

- Total or gross estimated biomass is 78 million bone dry tons (BDT) per year. Technical (recoverable) resource is estimated at 35 million BDT/y.
- Roughly 45% of the gross biomass resource is considered to be technically available for conversion or other uses. The remainder occur in sensitive habitat areas, on steep slopes not suitable for harvesting, are needed to maintain soil OM and fertility, or are unrecoverable by harvesting and recovery equipment.
- The 35 million BDT/y technical biomass resource, coupled with biogas generation from organic wastes already in place in landfills and biogas from existing anaerobic digestion facilities represents more than 4,630 MW and 35 TWh of electrical capacity.
- **Technical resources includes material currently used in existing bioenergy (~I GW capacity*), feed, mulch, compost, bedding and other markets**.
- **Availability for energy purposes depends on economic factors such as recovery and transportation costs, conversion technology and permitting/regulatory costs and competition with other end use markets**.



*including solid-fuel biomass, landfill gas-to-energy, and digester gas-to-energy. See CBC bioenergy facilities database: http://biomass.ucdavis.edu/files/2013/09/11-20-2013-cbc-facilities-database_1May_2013_update.xlsx. Williams et al., 2014, DRAFT report

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Estimates based on methods used in Task 3: No economic filters, no purpose-grown crops

Table 1: Estimated annual biomass residue amounts and fuel potential for California.

Feedstock	Amount Technically Available	Biomethane Potential (billion cubic feet)	Biofuel Potential (million gge)	Biofuel Potential PJ (LHV basis)§
Agricultural Residue (Lignocellulosic)	5.4 M BDT [a]	-	272 [h]	32.7
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Waste Water Treatment Plants	11.8 BCF (gas) [e]	7.7 [k]	66 [i]	7.9
Total			2,100	252.5

Source:
Williams et al., 2014

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Task 4 -- Integrated Assessment of Biomass Resources for Power and Fuels:

1. Purpose of integrated assessment (IA); why is it useful? necessary?
2. Analytical tools and methods;
3. Results for agricultural biomass
4. Forthcoming: (i) biomass from marginal lands (salt-affected areas, dry farmed regions, other);(ii) biopower from manure-based AD systems and groundwater protection (iii) geospatial assessments of forest biomass and sustainable economic potentials (bio-power focused).

(Results from Task 4 will add to Task 3 value (Biomass data base).

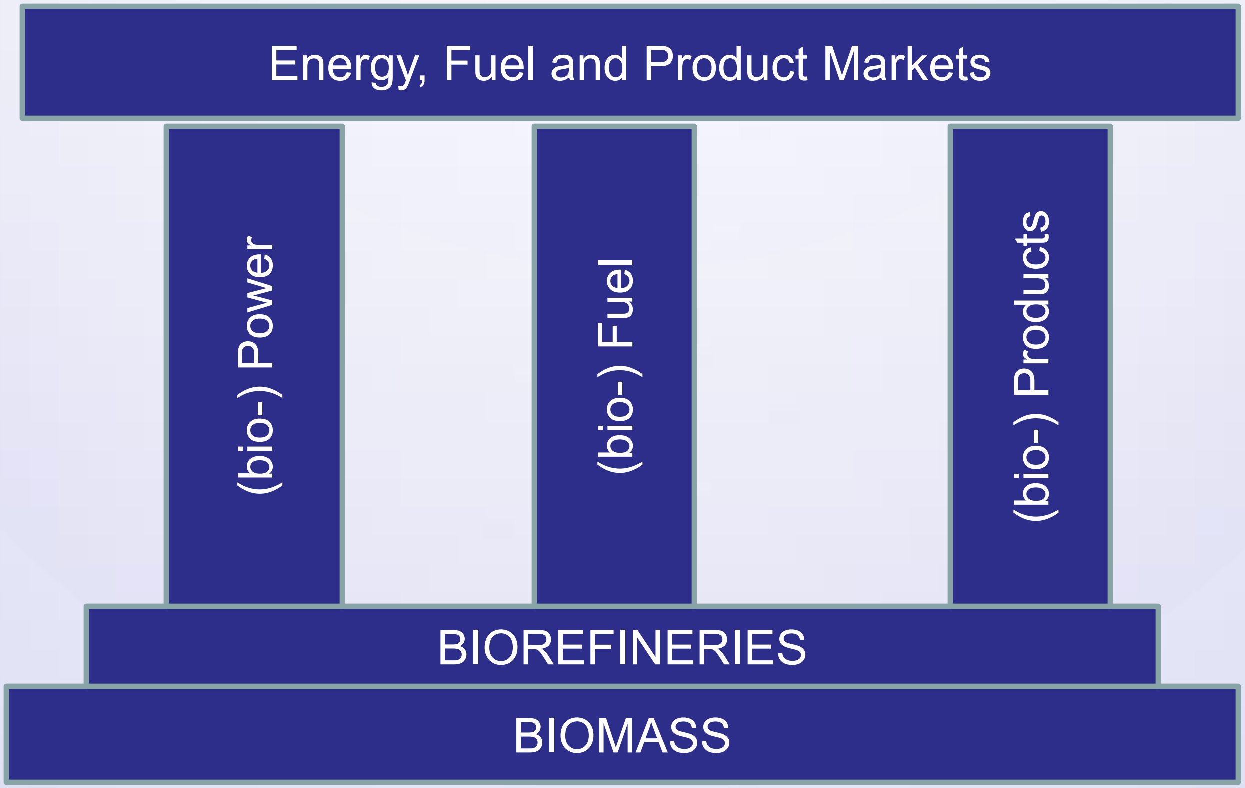
Biomass is complicated. There are many possible feedstocks and biomass conversion pathways. Policy and markets influence the pathways and products developed.

- Production
- Collection
- Processing
- Storage
- Transportation

- Thermochemical Conversion
  - Combustion
  - Gasification
  - Pyrolysis
- Bioconversion
  - Anaerobic/Fermentation
  - Aerobic Processing
  - Biophotolysis
- Physicochemical
  - Heat/Pressure/Catalysts
  - Refining
  - Makes e.g. Esters (Biodiesel), Alkanes

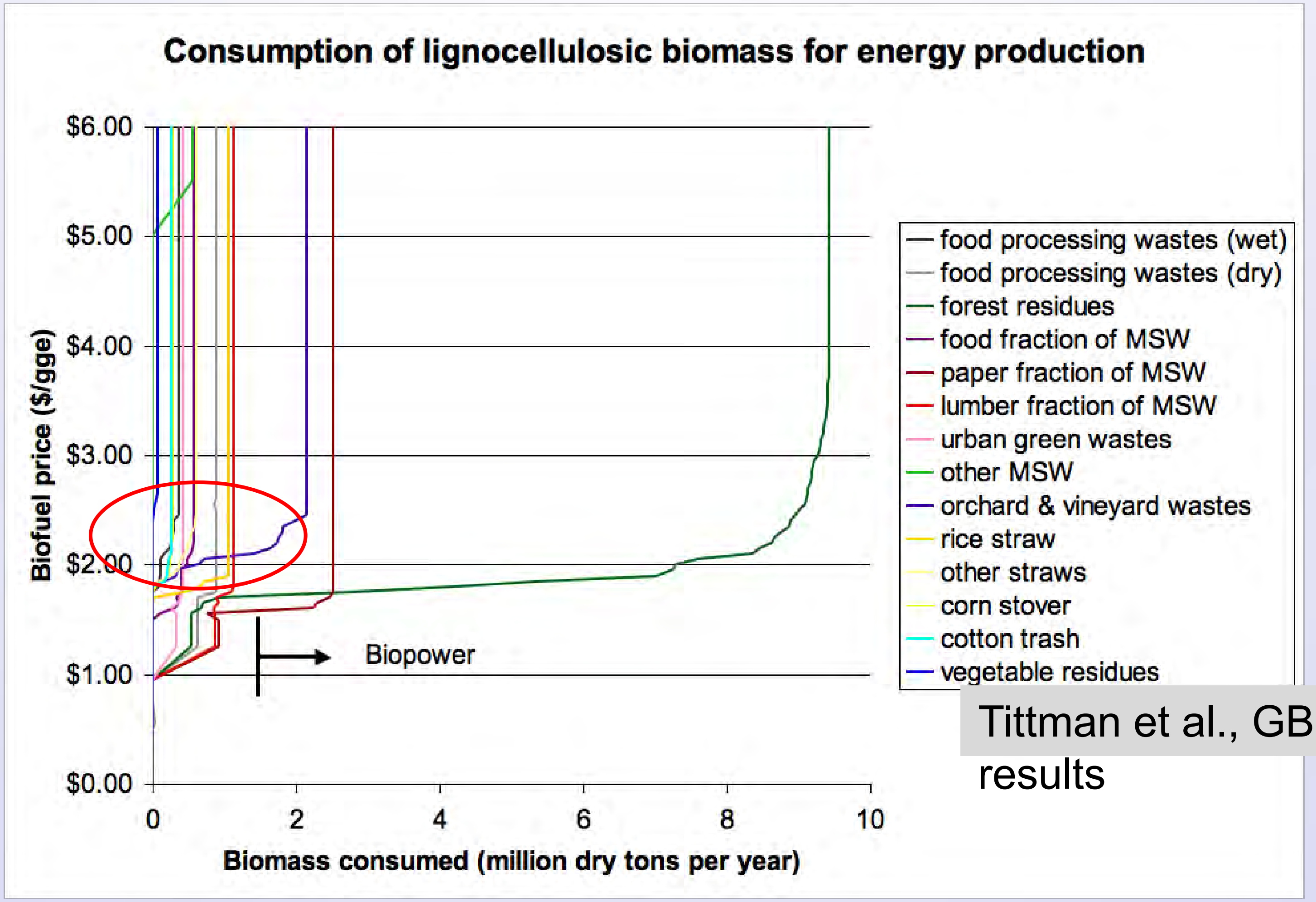
- **Energy**
  - **Heat**
  - **Electricity**
- Fuels
  - Solids
  - Liquids
  - Gases
- Products
  - Chemicals
  - Materials

Bio-based Economy



It is difficult to separate biomass use into power or fuel. Future biorefineries will produce a number of diverse energy outputs and diverse bio-products. The mixture will vary with local opportunities, optima and policy.

(Based on Kamm et al., 2011)



Tittman et al., GBSM results

Under many circumstances, biofuel prices result in use of biomass for transportation fuels rather than for power. More recently, power supplies have been considered to be a biofuel source. If expanded, this could change the relative economics of biomass use.

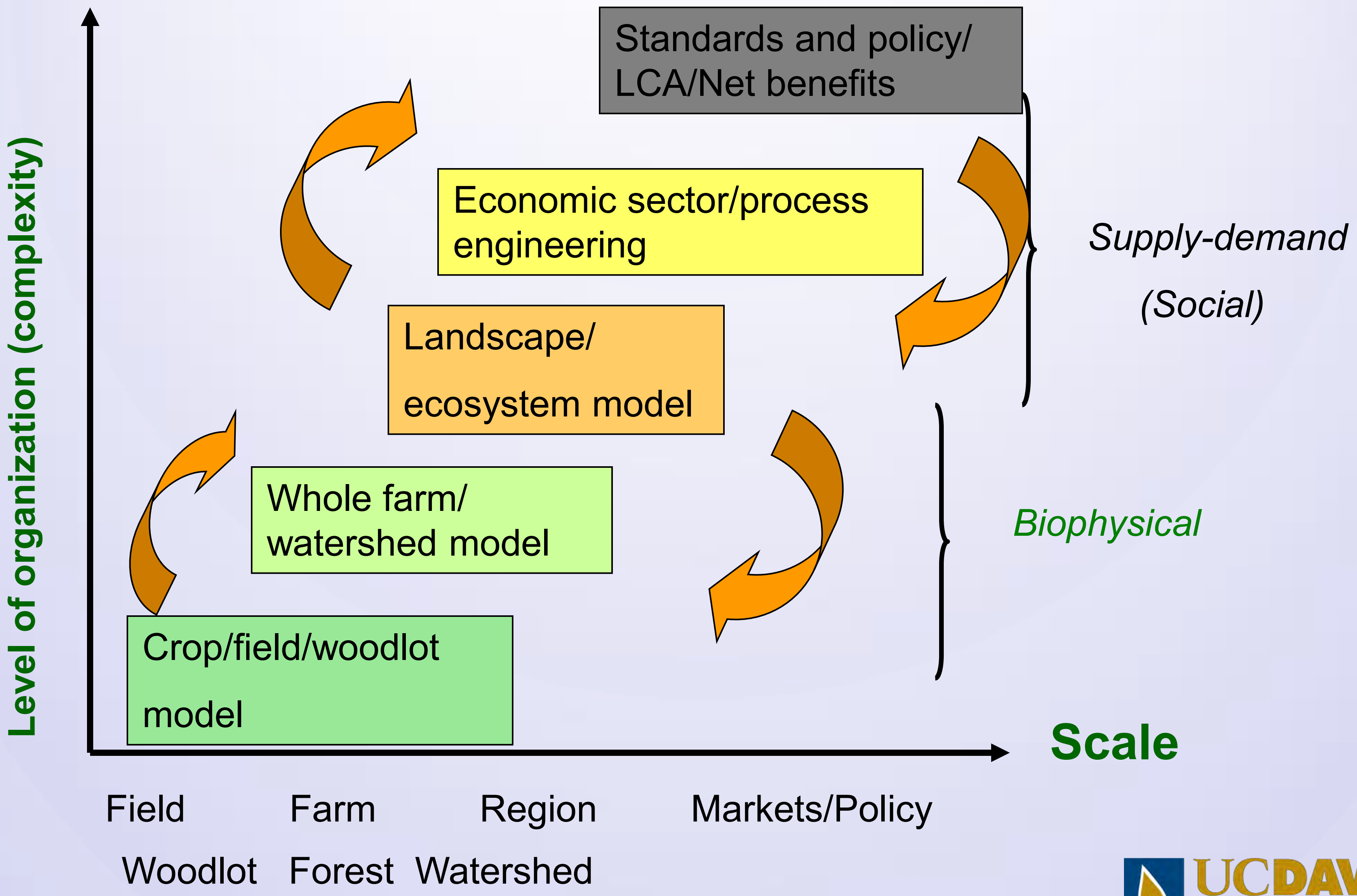
Why Integrated Assessments are needed:

The use of biomass for energy is commonly linked to significant effects on landscapes and existing economic and social arrangements. New uses may be disruptive and result in emissions or other unanticipated effects. This requires a broad consideration of the potential effects of biomass use. Challenges to governance and management of a broad-scale energy transition are unprecedented, complicated and susceptible to error. Tradeoffs are inevitable and unavoidable. IA provides a broader set of information with respect to new bioenergy systems and policies.

"Rising living standards and life expectancy require that some environmental resources are sacrificed in order to create the material well-being that may then enable people to place a higher value on the remaining stock of ecological assets."
Page 254 in Pennington, M. (2011). Robust Political Economy

"[Government planning of an economy] always involves a sacrifice of some ends in favour of others, a balancing of costs and results, and this presupposes a complete ranging of the different ends in the order of their importance..."
Hayek, F. (1938). Freedom and the Economic System.

Integrated Assessment should be based on sound practical understanding of feedstock acquisition and its limitations.



Based on van Ittersum et al., 2008)

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Why not use some of California's land, including now idled land, to produce feedstocks efficiently and create in-state jobs, especially in disadvantaged areas?

TASK 4: Can we have in-state agricultural feedstock production for bioenergy in California?

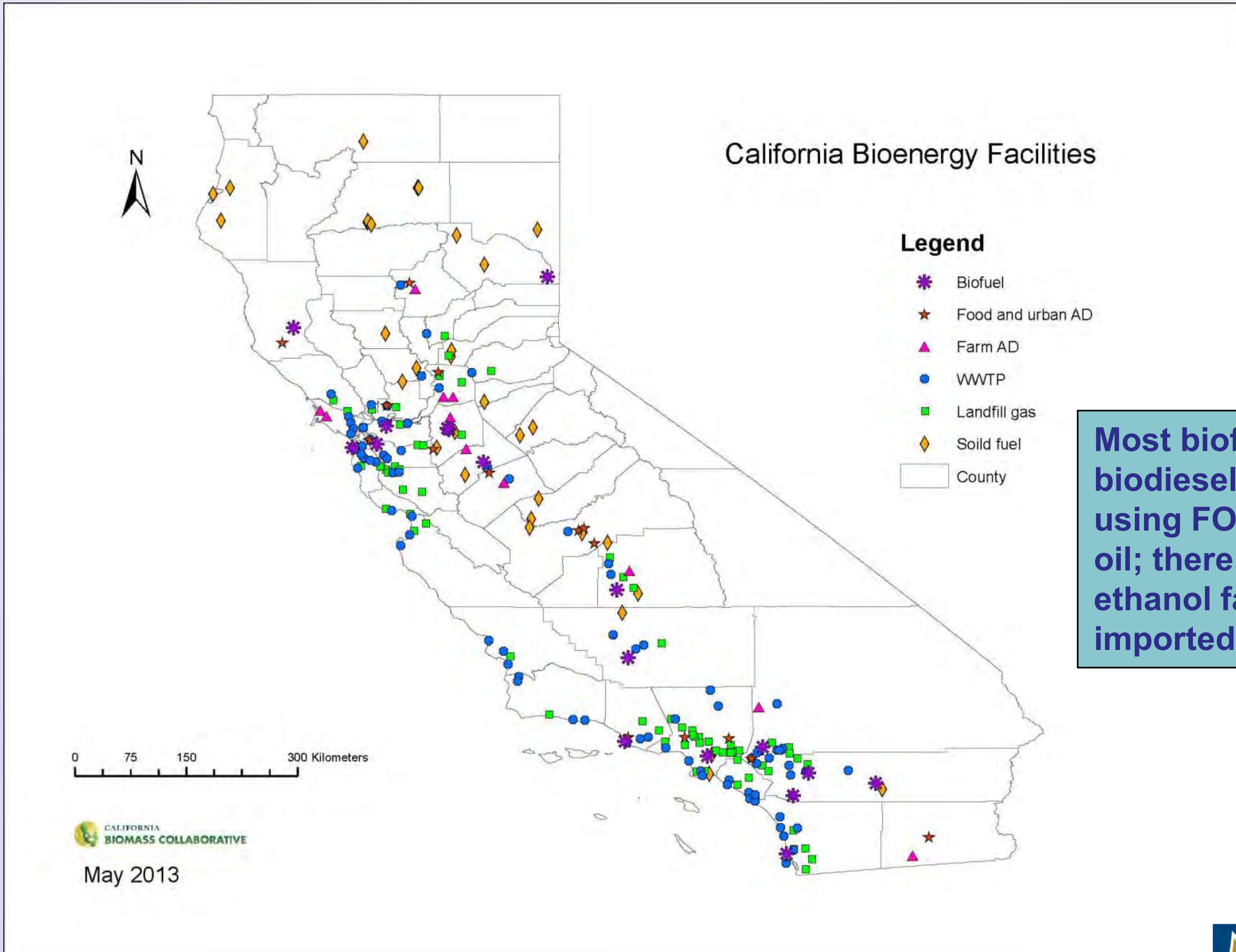
- **Stephen Kaffka, Boon-Ling Yeo, Taiying Zhang, Mark Jenner,**
- University of California, Davis & California Biomass Collaborative

The approach and methods developed for crop-based energy systems apply to forestry and other biomass feedstock sources.

TASK 4: Integrated Assessment- analyses included

- **Identification of most likely opportunities in California for bioenergy/biofuel from agriculture (crops, marginal lands, residues)**
- Economic analysis and land use (crop adoption and substitution) and location
- GHG emissions
- Likely biorefinery technology
- Jobs, regional economic impact
- Water use, wildlife and soil erosion effects
- Compliance with sustainability concepts
- Role(s) in remediation

California Renewable Energy Center



Most biofuel facilities are biodiesel manufacturers using FOG and vegetable oil; there are 4 larger ethanol facilities using imported corn grain

Recent applications to the AFRVTP (AB 118) program (agricultural feedstocks)

Applicant	Project Title	Grant	Feedstocks	Location	Fuel Type/Size	Size	Status
Mendota Advanced Bioenergy Beet Cooperative	Advanced Bioenergy Center Mendota	PON-09-604	Sugar Beets	Mendota	Biofuel ethanol	285,000 gal/year	Awardee
Great Valley Energy, LLC	Feasibility of Fractioned Sweet Sorghum to Ethanol and Products	PON-09-604	Sweet Sorghum	San Joaquin Valley	Biofuel ethanol	3.15 M gal/year	Awardee
EdeniQ Inc.	California Cellulosic Ethanol Biorefinery Utilizing California Waste Products and Feedstocks	PON-09-604	Corn stover, switchgrass, and wood chips	Visalia	Cellulosic ethanol	50,000 gal/year	Not Funded
Alt Air Fuels, LLC	Feasibility Study for Renewable Jet and Diesel Fuels Biorefinery	PON-09-604	Camelina Oil	Seattle	Biofuel diesel	30 M gal/year	Not Funded
California Ethanol & Power, LLC	Sugarcane-to-Ethanol and Electricity Production Facility	PON-09-604	Sugarcane	Imperial Valley	Ethanol and Electricity		Not Funded
Amyris Biotechnologies, Inc	Renewable Hydrocarbon Diesel Production from Sweet Sorghum and Sugar Cane	PON-09-604	Sweet Sorghum	Thousand Oaks	Biofuel diesel		Did Not Pass
Pacific Ethanol Inc.	Madera Combined Heat and Power	PON-09-604	Grain Sorghum	Madera	Cellulosic ethanol	40 M gal/year	Did Not Pass
Pacific Ethanol Inc.	Incorporation of Cellulosic Ethanol Technology into Pacific Ethanol's Stockton Facility	PON-09-604	Grain Sorghum	Stockton	Cellulosic ethanol		Did Not Pass
California Biofuels, LLC	Sweet Sorghum & Agriculture Waste Project	PON-09-604	Sweet Sorghum				Did Not Pass
Mendota Bioenergy, LLC (MBLLC)	Advanced Biorefinery Center-Mendota Integrated Demonstration Plant	PON-11-601	Sugar Beets	Mendota	Biofuel ethanol	285,000 gal/year	Awardee
ZeaChem Inc.	Pilot Plant and Commercial Feasibility Study for Biobased Gasoline Blendstocks	PON-11-601					Awardee
EdeniQ Inc.	California Cellulosic Ethanol Biorefinery	PON-11-601	Corn stover, switchgrass, and wood chips	Visalia	Cellulosic ethanol	50,000 gal/year	Awardee
Canergy, LLC	Pre-Work Low-Carbon Ethanol Production from Sugarcane and Sweet Sorghum	PON-11-601	Sugarcane and Sweet Sorghum	Imperial Valley	Cellulosic ethanol		Not Funded
Pacific Ethanol Development, LLC	Madera Biomass Refinery	PON-11-601					Not Funded
California Ethanol & Power, LLC (CE&P)	Permitting for California Sugarcane Ethanol Plant	PON-11-601	Sugarcane	Imperial Valley	Ethanol and Electricity		Did Not Pass
Partnership for Environmental Progress, Inc.	Agave Biofuel Feasibility Study	PON-11-601					Did Not Pass

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TASK 4: Integrated Assessment- analyses included

- Identification of most likely opportunities in California for bioenergy/biofuel from agriculture (crops, marginal lands, residues)
- **Economic analysis and land use (crop adoption and substitution) and location**
- GHG emissions
- Likely biorefinery technology
- Jobs, regional economic impact
- Water use, wildlife and soil erosion effects
- Compliance with sustainability concepts
- Role(s) in remediation

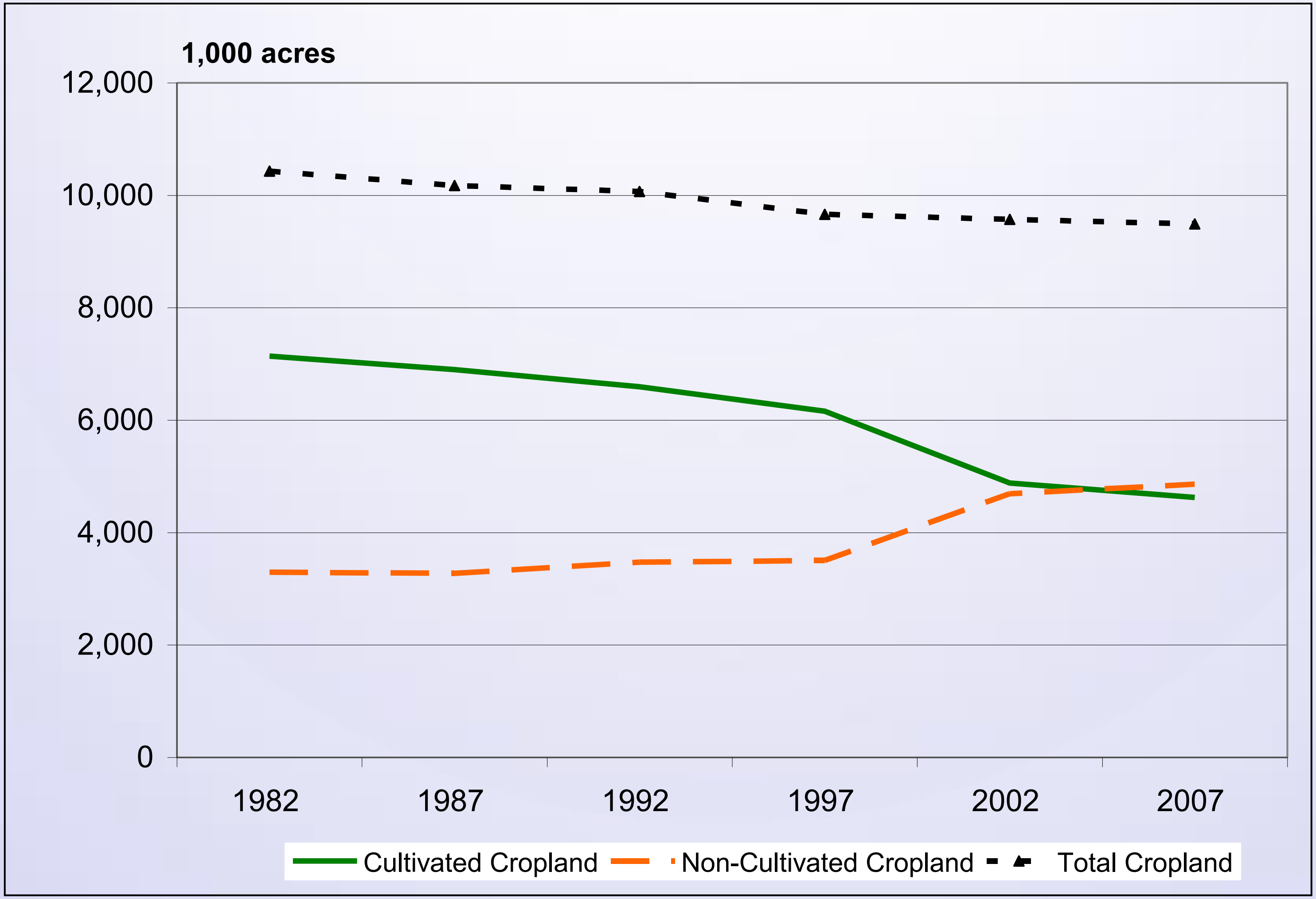
2010 USDA Biofuels Roadmap Estimates

Advanced Biofuel Production from New Capacity (billion gallons)

Region	% of Total Advanced Volume	Advanced Biofuels: Ethanol	Advanced Biofuels: Biodiesel	Total Advanced Volume	Total Advanced RFS2 Basis (1)
Southeast (2)	49.8	10.45	0.01	10.46	10.47
Central East (3)	43.3	8.83	0.26	9.09	9.22
Northeast (4)	2.0	0.42	0.01	0.42	0.43
Northwest (5)	4.6	0.79	0.18	0.96	1.05
West (6)	**<0.3**	**0.06**	**0.00**	**0.06**	**0.06**
United States		20.55	0.45	21.00	21.23

(1) RFS2 Basis - higher density fuels receive higher weighting relative to ethanol. Biodiesel is 1.5
(2) Feedstocks: Perennial grasses, soyoil, energy cane, biomass (sweet) sorghum, logging residues
(3) Feedstocks: Perennial grasses, canola, soyoil, biomass (sweet) sorghum, corn stover, logging residues
(4) Feedstocks: Perennial grasses, soyoil, biomass (sweet) sorghum, corn stover, logging residues
(5) Feedstocks: Canola,straw, logging residues
(6) Feedstocks: Biomass (sweet) sorghum, logging residues

USDA (from Washington) predicted little bioenergy production from crops in California or elsewhere in the western US.



Changes in California cultivated and non-cultivated cropland, 1982-2007 (USDA, NRCS, 2009). Non-cultivated cropland = tree and vine crops predominantly

On an agro-ecological basis, there are many feedstock crop possibilities in California due to high yields and RUE and unusual cropping systems.

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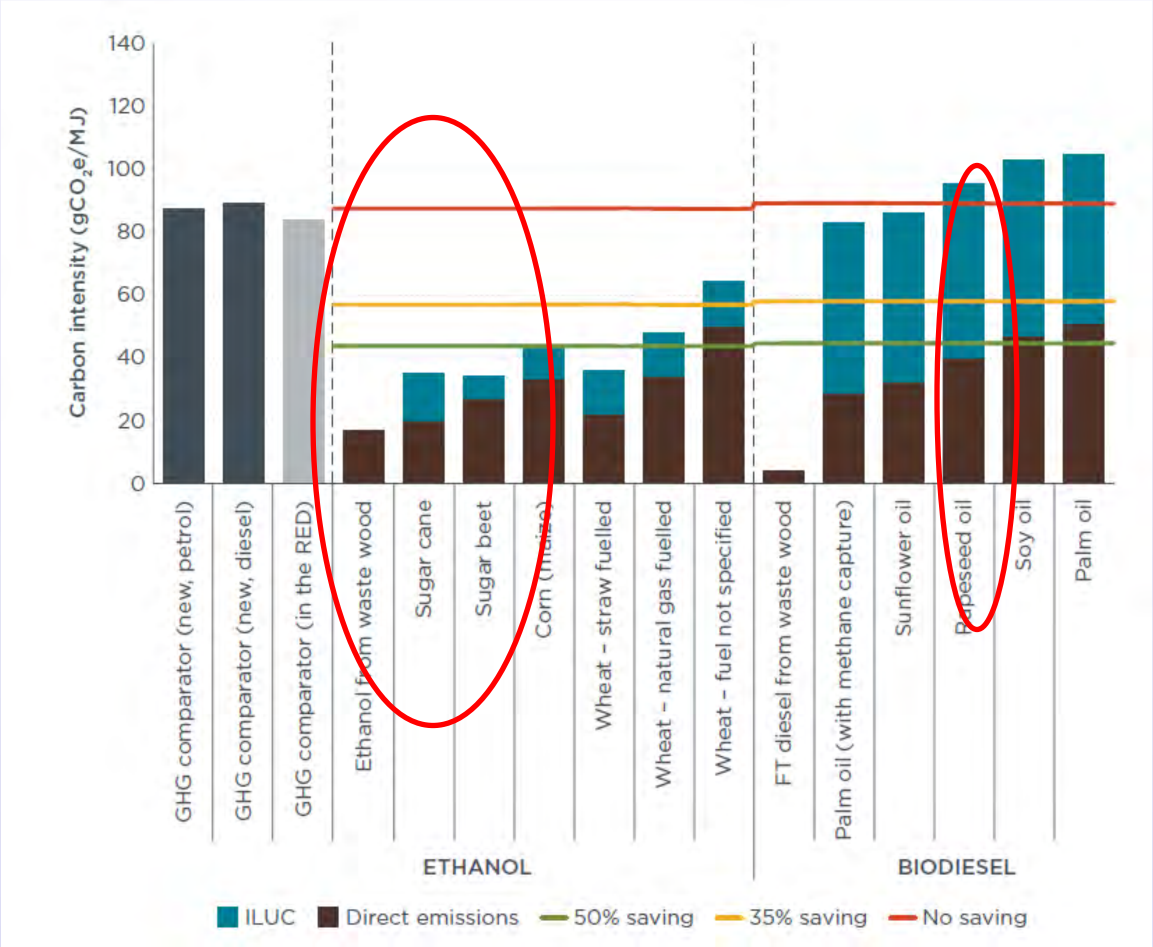
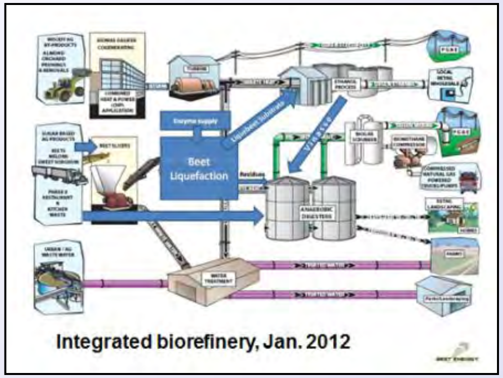
Potential GHG savings estimates from alternative feedstocks based on ALCA; (European values).



Source: ICCT, 2014.

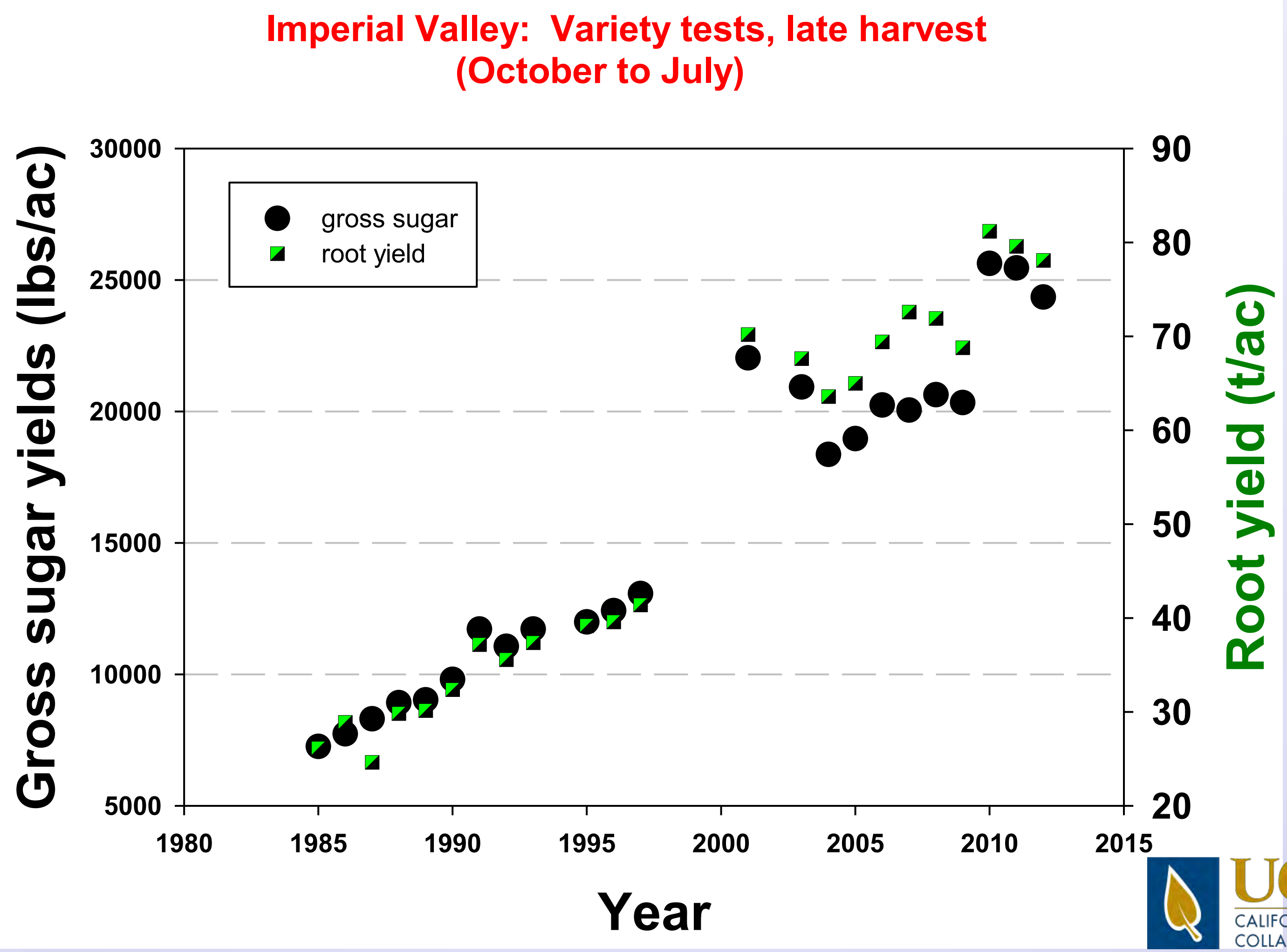
http://www.theicct.org/sites/default/files/publications/ICCTupdate_EU_ILUC_july2014.pdf



Integrated biorefinery, Jan. 2012

Potential ethanol yields from selected feedstocks. Crops like beets can be produced with high yields and efficiency using current or near–term technology. Cellulosic or low quality feedstock sources have been slow to enter the market, and are less likely to be produced in California. Converting them involves significant capital costs. Light blue, current or simple technology, mid-blue (new of pilot-scale technology) and dark blue (no current technology available-the theoretical conversion limit). Data from diverse sources.

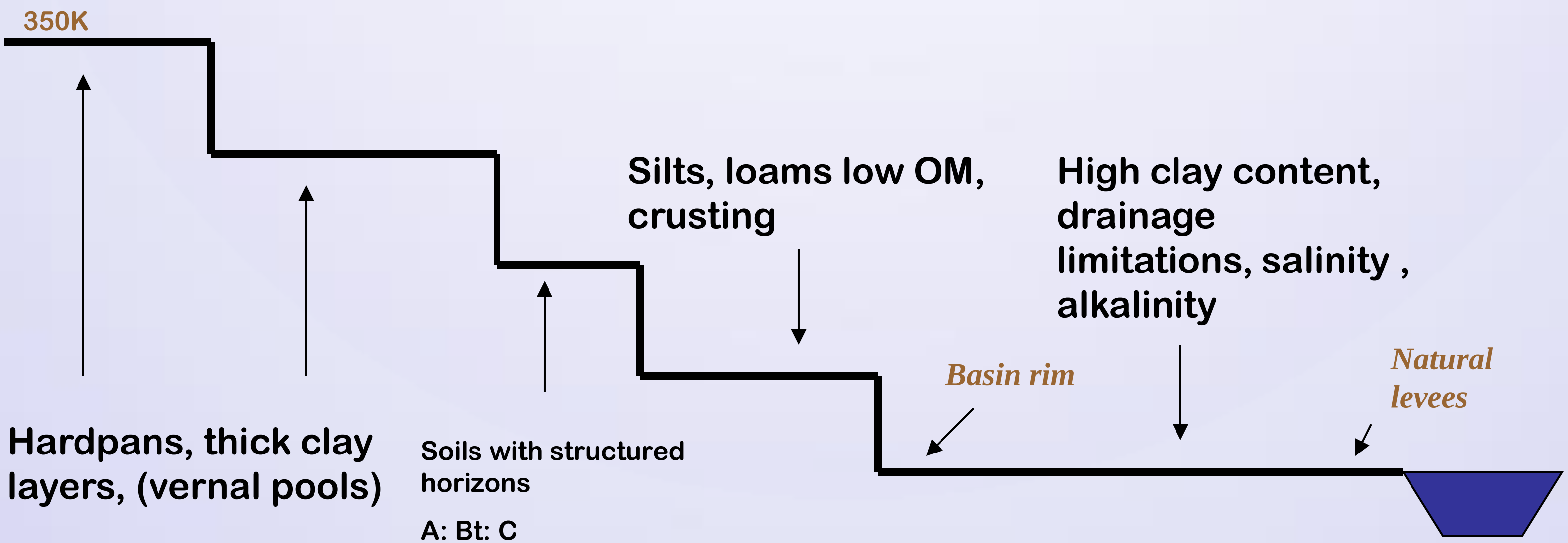
Increasing yields and returns to total factor productivity over time support the use of some crops for bioenergy. Here sugar beets.



Diverse soils and landscapes lead to differing cropping systems in CA

Soil age: --→

oldest 100K 30-80K 10K youngest

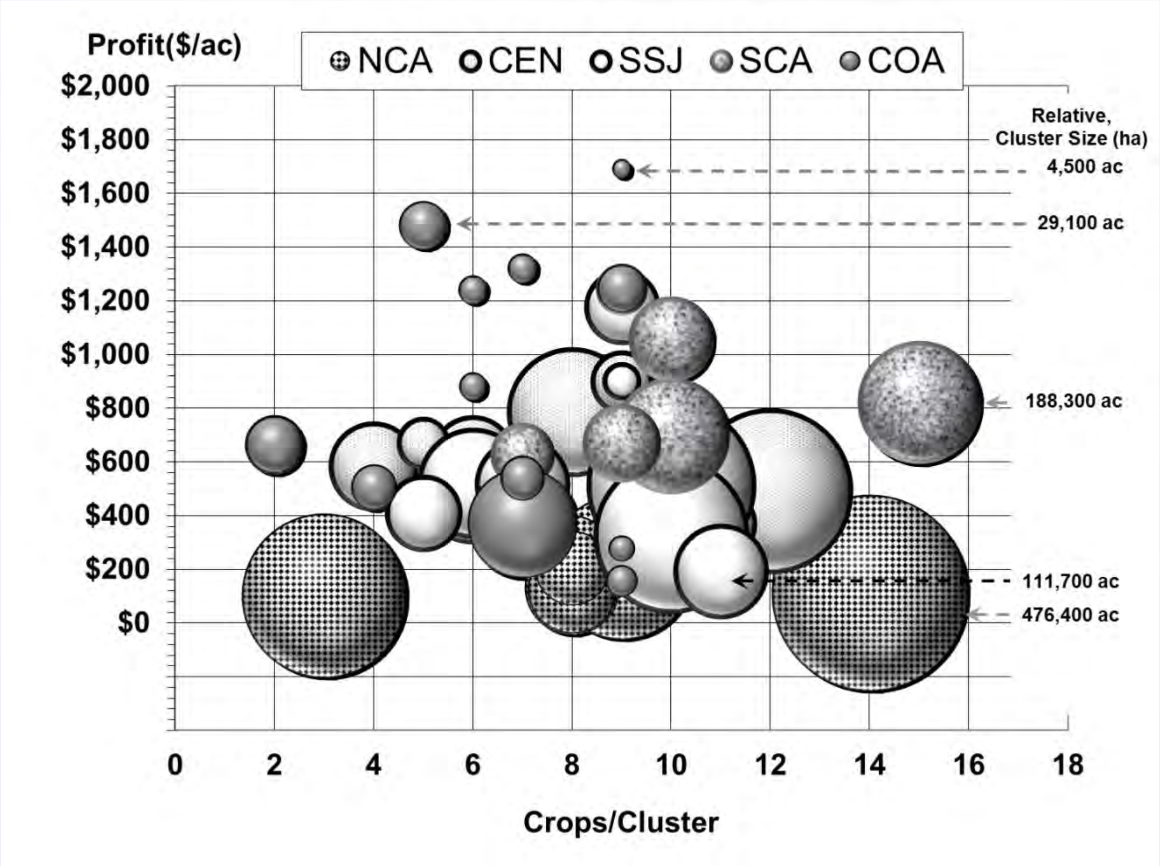


Oak-savanna/rangelands

rangeland/pasture, some perennials

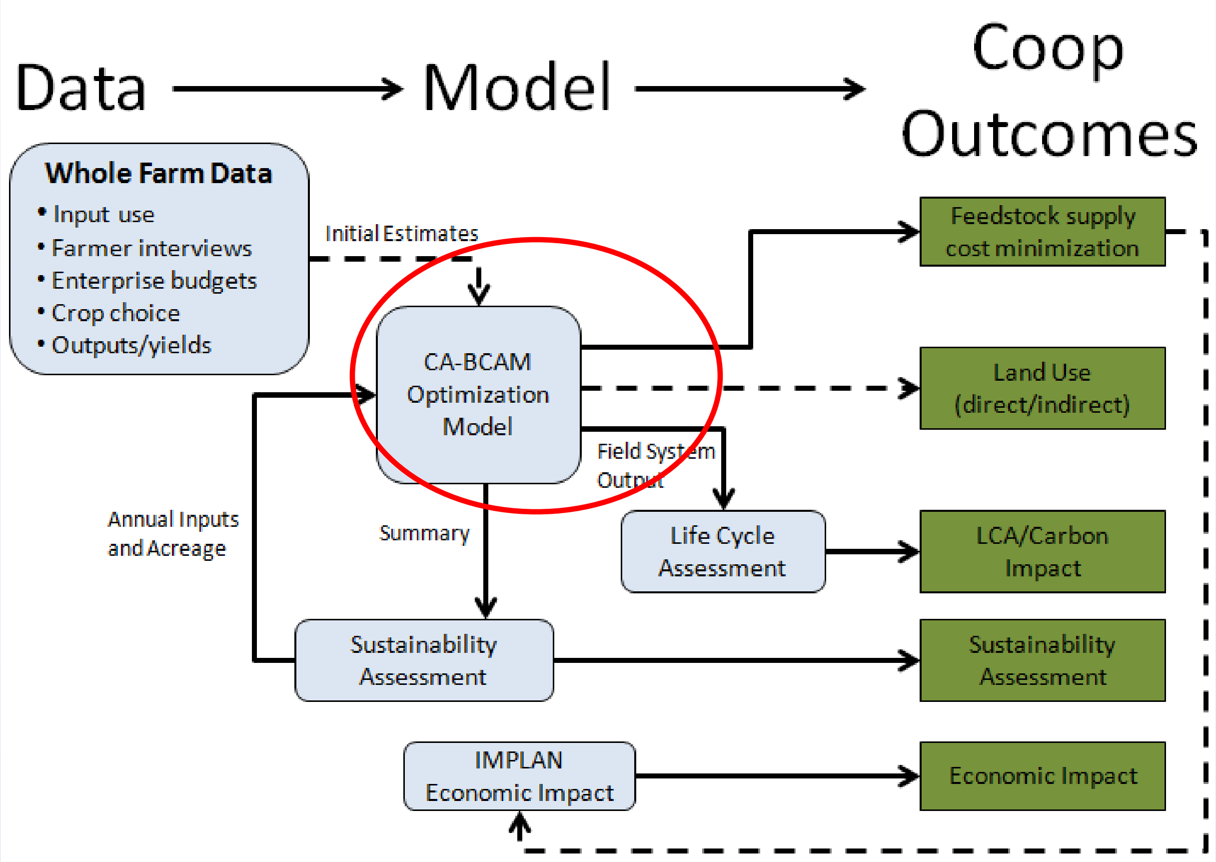
Soil use → perennials, annuals mostly annuals

Per Acre Profit for 45 Regional Farming Systems (2000-10 PUR data)



NCA: Sacramento Valley; CEN: Delta and northern SJV; SCA: Tulare, Kings, Kern; SCA: Imperial Valley, Palo Verde, San Diego; COA: Salinas Valley, Santa Maria, Ventura; **PUR = CA DPR Pesticide Use Data**

Information transfer/ systems analysis /LCA/ and sustainability. BCAM provides basis for quantifying positive and negative cropping system interactions.



The complementarity among models and the integration with the state's LCFS is discussed in the report in detail. At some point, power systems should be compared on a performance-standard basis as well.

California Bioenergy Crop Adoption Model (BCAM). BCAM is a crop rotation optimization model that estimates prices needed for new crops and crop displacement. It can work at the regional or farm level, and tests new crops against longer term cropping patterns in diverse areas of the state.

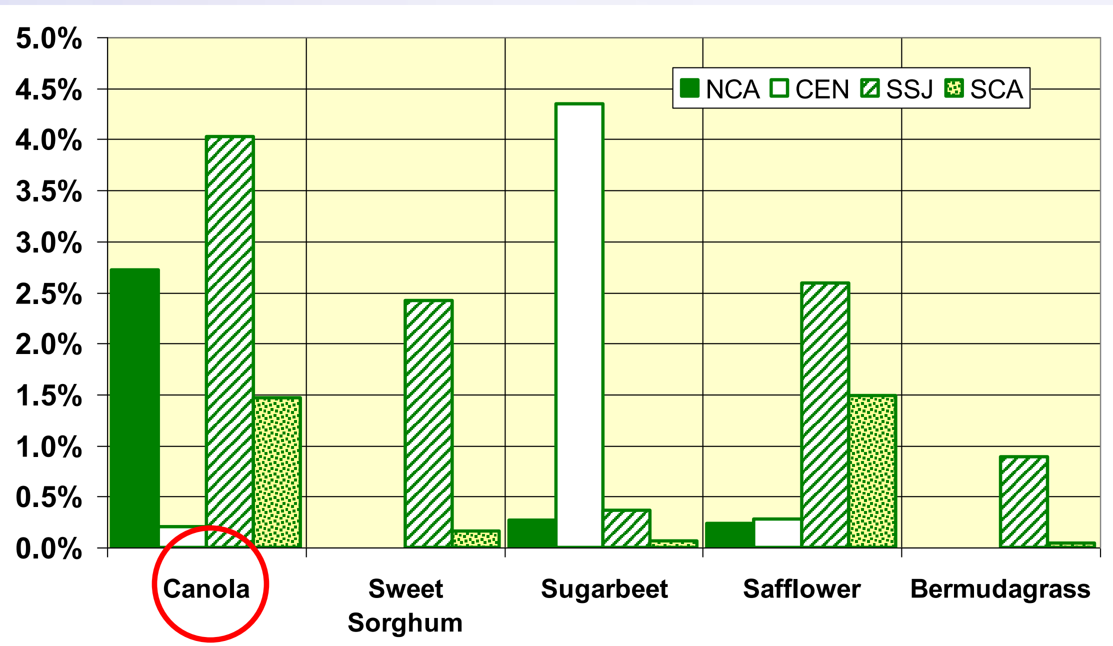
Production function

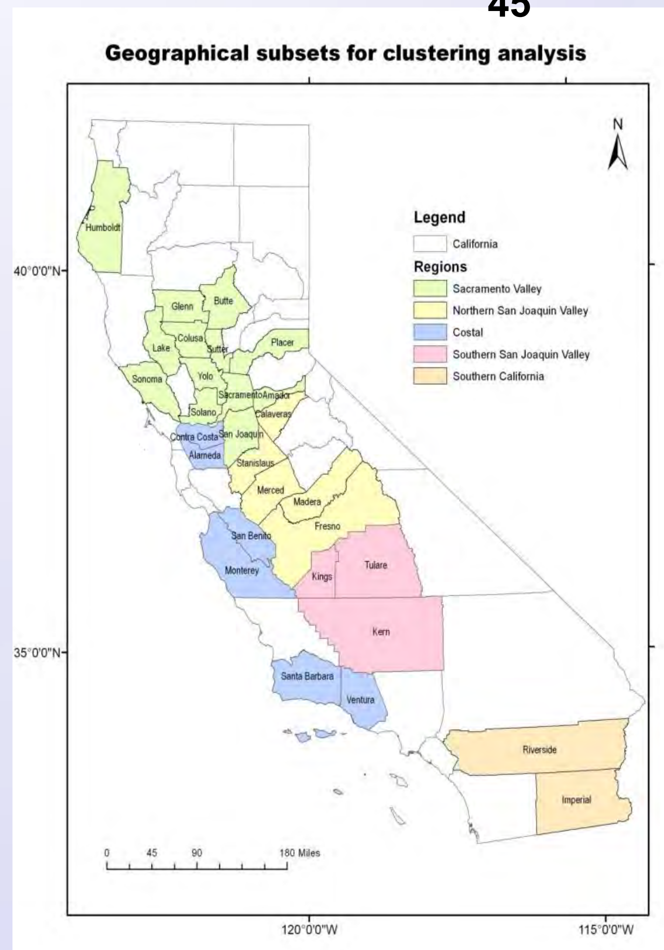
$$\underset{X_{e,g,i,j}}{Max} \prod_{\bar{A}} \sum_g \sum_j \left[\underbrace{\sum_i \left(P_{g,i,j} \times \left(\beta_{g,i,j} - \omega_{g,i,j} X_{g,i,j} \right) - C_{g,i,j} \right) X_{g,i,j}}_{\text{PMP function}} + \underbrace{\sum_e \left(P_{e,g,j} Y_{e,g,j} - C_{e,g,j} \right) X_{e,g,j}}_{\text{Energy crop function}} \right]$$

Subject to: $\sum_i \sum_e X_{g,i,e,j} \leq \overline{A_{g,j}}$ j= {*acres, ac-ft of water*}

$P_{e,g,i,j}$	= farm price of crop *i*, and energy crop *e*, in region *g*, and resource, *j*.
$C_{e,g,i,j}$	= farm cost of crop *i*, and energy crop *e*, in region *g*, and resource, *j*.
$Y_{e,g,i,j}$	= yield of crop, *i*, and energy crop *e*, in region, *g*, and resource, *j*.
$X_{e,g,i,j}$	= level of hectares *r* applied to energy crop e, in region *g* for crop *i*.
$\bar{A}_{g,j}$	= constrained hectares of crop *j* in region *g*.
$\beta_{g,i,j}$	= intercept of the quadratic (marginal) curve of crop, *i*, in region, *g*, resource, *j*.
$\omega_{g,i,j}$	= slope of quadratic (marginal) curve of crop, *i*, in region, *g*, and resource, *j*.

Region	model code	Crop Acres (Census of Ag)	Annual Crop Acres	Total Counties	DPR Counties	Crop/Farm Clusters
Northern CA	NCA	3,190,441	1,538,971	29	14	9
Central CA	CEN	2,314,332	1,179,789	9	5	9
South SJV	SSJ	2,094,486	1,193,752	3	3	8
Southern CA (IV)	SCA	818,787	599,237	6	2	6
Coastal CA	COA	1,038,340	395,633	11	6	13
		9,456,386	4,907,383			45

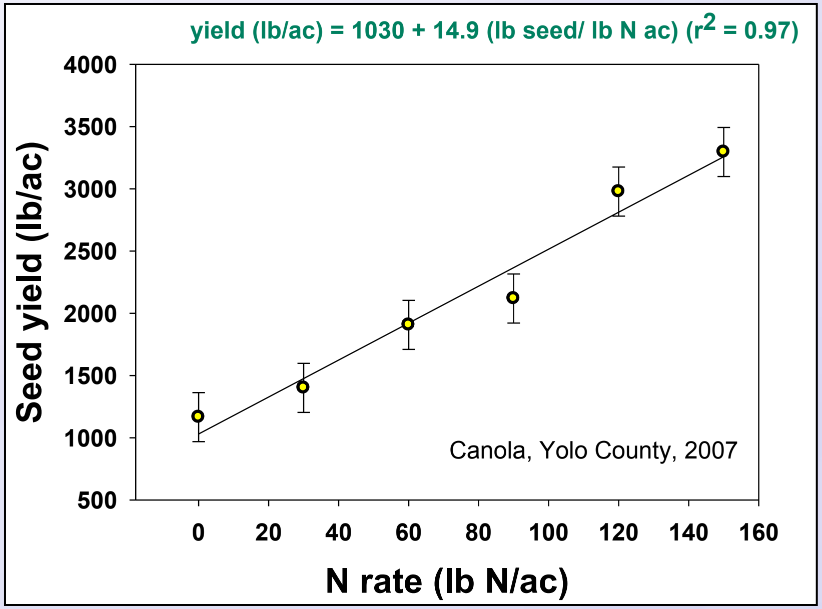




Feedstocks evaluated: winter annual oilseeds, energy beets, sugar cane, energy cane, grain and sweet sorghum, Bermuda grass, Jose tall wheat grass, (poplars).

Estimated cost per hectare to produce canola in California (base year: 2012).

INPUT	Quantity (per Ac)	UNIT	Cost/Unit	Total
FERTILIZER				**$227.90**
Nitrogen (dry)	175	lb	$0.74	$129.50
Phosphorous (dry)	20	lb	$0.74	$14.80
Potassium (dry)	120	lb	$0.54	$64.80
Sulfur (dry)	20	lb	$0.94	$18.80
PESTICIDES				**$56.40**
Assure II	2	pint	$20.00	$40.00
Ammonium Sulfate	4	pint	$0.35	$1.40
M90	50	ml	$0.05	$2.50
Capture	1	Ac	$12.50	$12.50
SEED				**$48.00**
Canola	6	lb	$8.00	$48.00
LABOR				**$47.17**
Labor (Machine)	2.1	hrs	16.08	$33.77
Labor (non-machine)	1	hrs	13.4	$13.40
FUEL				**$30.87**
Diesel	9	gal	$3.43	$30.87
REPAIR & MAINTENANCE				**$12.80**
Lubricants	1	Ac	$2.20	$2.20
Repair	1	Ac	$10.60	$10.60
CUSTOM & CONSULTANT				**$31.37**
Rental Sprayer	1	Ac	$2.16	$2.16
Custom Aerial Spray	1	Ac	$8.03	$8.03
Rental Ripper Shooter	1	Ac	$6.18	$6.18
Soil Test	1	Ac	$15.00	$15.00
OTHERS				**$266.53**
Overhead				$ 250.00
Crop Insurance				$ 10.00
Interest on Operative Capital				$ 6.53
Total Cost per Acre 2012				$721.04
Total Cost per Acre 2007				$659.09
Yield per Acre				2,500 lb



Example budgets based on cost accounts data and agronomic information.

Outputs from BCAM modeling

Regional entry prices for canola at different adoption levels (i.e. number of acres) measured in dollars per ton.

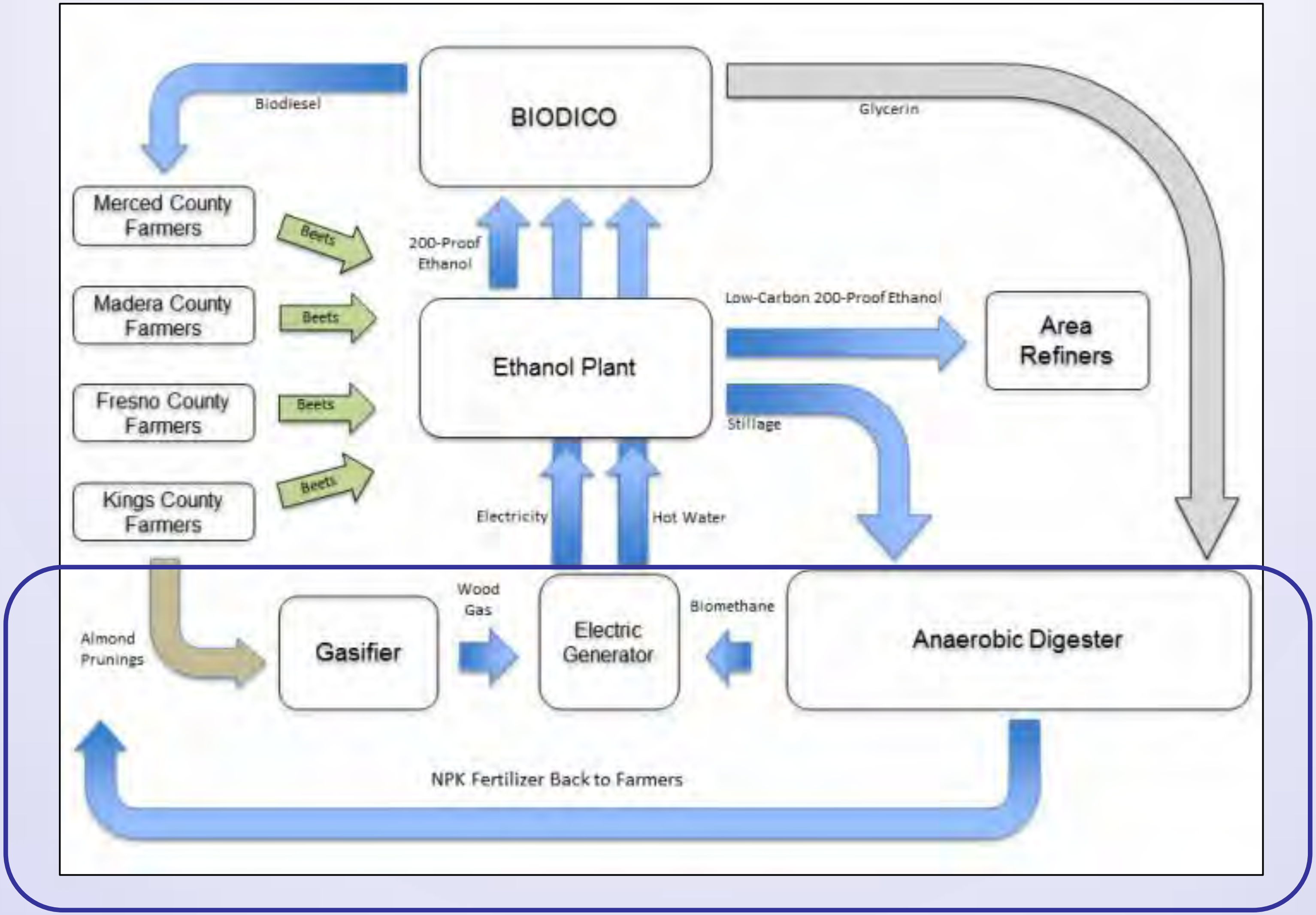
Number of Acres	Sacramento Valley		Northern San Joaquin Valley		Southern San Joaquin Valley		Southern California		Coastal	
5,000	$	313.02	$	350.18	$	307.20	$	358.92	$	569.08
25,000	$	336.44	$	355.48	$	310.74	$	558.96	$	569.86
50,000	$	360.47	$	362.11	$	315.16	$	593.25	$	570.83
100,000	$	430.21	$	395.59	$	324.01	$	608.02	$	572.78

Crop displacement in the five California regions because of introduction of 100,000 acres of Canola.

Sacramento Valley		Northern San Joaquin Valley		Southern San Joaquin Valley	
Wheat	34,571	Cotton	83,266	Cotton	34,485
Oath	15,426	Wheat	7,327	Wheat	20,462
Corn	14,259	Lettuce	2,985	Oath	14,241
Alfalfa	10,127	Corn	2,667	Corn	13,390
Safflower	7,355	Beans	2,294	Beans	13,187

There are also opportunities to use vineyards and orchards for feedstock production. (no ILUC)

http://cestanislaus.ucanr.edu/files/111327.pdf



Mendota Bioenergy LLC, Advanced Biorefinery Center (15 mg/y (170.3mL/y) ethanol facility); one of two proposed in California. Mendota is located in the San Joaquin Valley region. The sugar factory there was closed in 2008.

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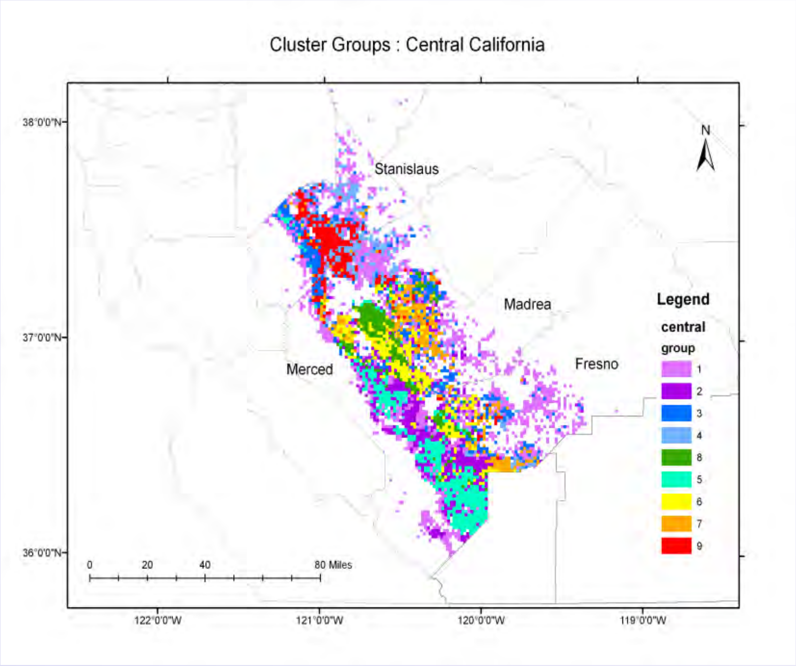
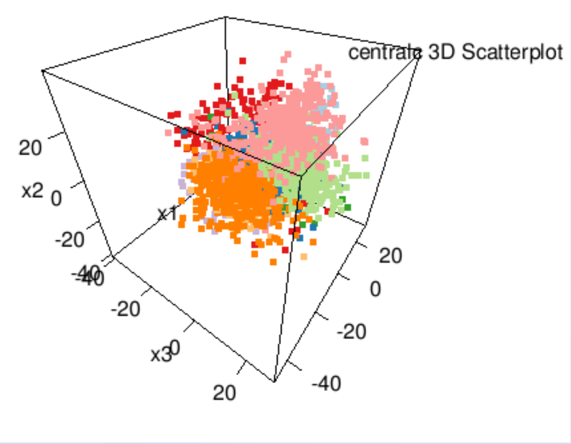
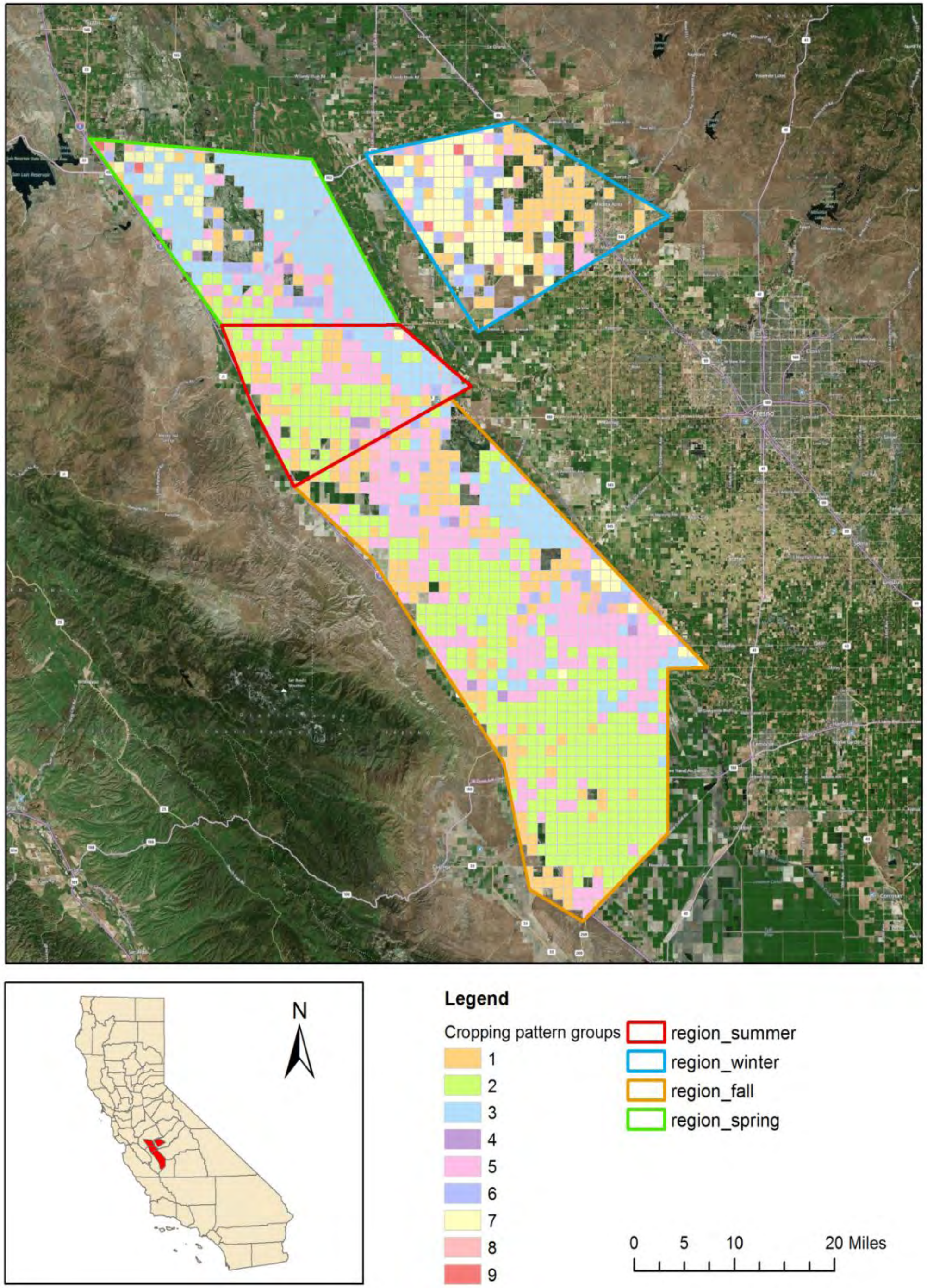
Regionalized cropping system locations and beets sources by time of year.







BCAM Results for Energy Beet Adoption: Entry Prices and Crop Displacement by Region (2007 prices)

Price of Sugarbeet ($/ton)	Sacramento Valley	Northern San Joaquin Valley	Sothern San Joaquin Valley	Cumulative Adoption
$ 37.80	1,568			1,568
$ 37.90	44,470			46,039
$ 38.50		13,457		59,495
$ 39.00		44,470		103,966

			Northern San Joaquin Valley			Southern San Joaquin Valley		
		160,474	Sudan hay	-100.00%	16,876	Bean	-100.00%	17,932
		102,314	Bean	-28.73%	11,990	Cotton	-3.48%	5,158
		10,302	Corn	-6.58%	9,913	Oat hay	-6.72%	2,013
		1,985	Rice	-0.19%	743	Corn silage	-0.26%	239
Bean	-1.62%	862	Wheat	-0.80%	691	Barley	-1.23%	92
An increase in crop production due to the adoption of sugarbeet (acres)								
Broccoli	0.19%	21	Oat hay	4.07%	3,755			
Wheat	2.07%	1,288						

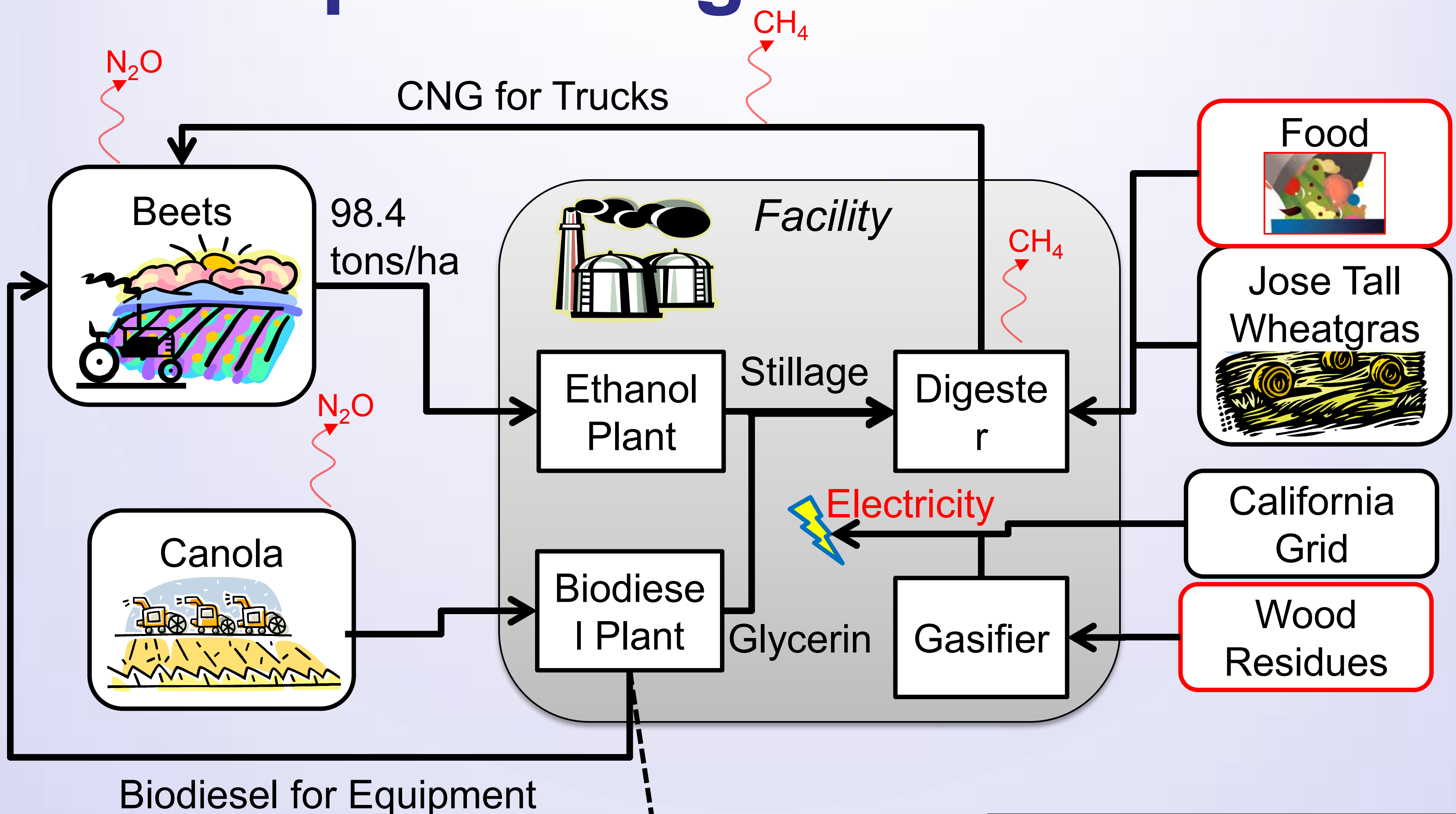
Estimated likely new near-term bioenergy production (fuels) from diverse agricultural feedstocks in California.

Crop	Commodity	Current Price (2013-14)	BCAM entry price (2007)	Location with most likely adoption	Estimated acres	Fuel type	Yield (as harvested)	Feedstock cost			In-state potential	Assumptions#		
	$/ton	$/ton	$/ton				gal/ton	$/gge	gge/ac	gge/ton	Mgge/y	lb/ac	t/ac	Quality
Canola	seed	475	385	SAC, SJV	100	Biodiesel	129.15	2.85	169	135.22	16.9	2500	1.25	43% oil
	meal													
Camelina	seed	340*	525	SAC, SJV	0	Biodiesel	96.11	5.22		100.63	0	1600	0.8	32% oil
	meal													
Sorghum	grain		134-139	SAC, SJV	100	Ethanol	110.95	1.81-1.88	296	73.97	29.59	8000	4	
Sorghum	sugar*		23.75	SJV, IV	15	Ethanol	21.54	1.65		14.36	8.62		40	13% brix
	livestock feed													
	biogas					CNG								
Beets	sugar**	65	40	NSJV, SAC	60	Ethanol	25.2	2.38	672	16.8	40.32		40	16% sucrose
	livestock feed													
	biogas					CNG								
Sugarcane	sugar***	65	45	IV	60	Ethanol	21.54	3.13	646	14.36	38.78		45	13% brix
	bagasse					Electricity					50 MW			
	biogas					CNG					930 MSCF			
Energy cane ##	bagasse		45	IV	40	Ethanol	63-79.2	0.85-1.07	622-781	42-52.8	31.9-40.1		45###	
	biogas					Electricity								
Total											142.3			

TASK 4: Integrated Assessment- analyses included

- Identification of most likely opportunities in California for bioenergy/biofuel from agriculture (crops, marginal lands, residues)
- Economic analysis and land use (crop adoption and substitution) and location
- **GHG emissions**
- Likely biorefinery technology
- Jobs, regional economic impact
- Water use, wildlife and soil erosion effects
- Compliance with sustainability concepts
- Role(s) in remediation

Conceptual Diagram for LCA



Alexiades and Kendall, 2013

Canola meal: Displaces soybean meal at its protein ratio of 1:0.88

Notes

- Denotes non-combustion greenhouse gas emissions
- Emissions from combustion occur throughout

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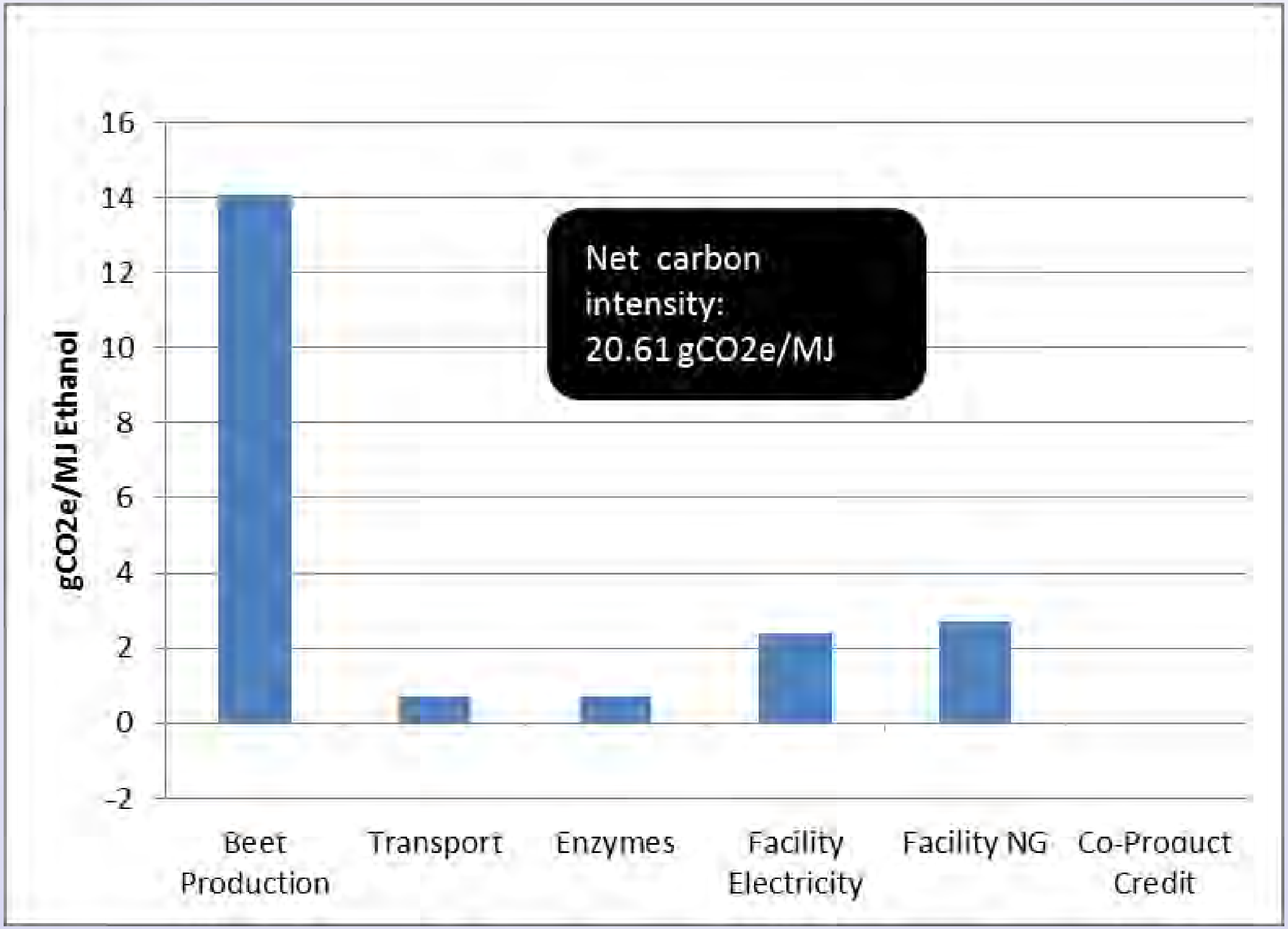

A. Alexiades and A. Kendall, 2013

15 minute break

Program will resume at 3:00 pm

TASK 4: Integrated Assessment- analyses included

- Identification of most likely opportunities in California for bioenergy/biofuel from agriculture (crops, marginal lands, residues)
- Economic analysis and land use (crop adoption and substitution) and location
- GHG emissions
- Likely biorefinery technology
- **Jobs, regional economic impact**
- Water use, wildlife and soil erosion effects
- Compliance with sustainability concepts
- Role(s) in remediation

How many jobs in a typical ethanol facility?

In California, self-reported direct employment at corn grain ethanol facilities ranges from 35 to 45 people per plant.

Normally, ethanol plants operate 24/7/7 with 4 shift teams. More people are on the Daylight Shift when incoming and outgoing materials are handled and when routine maintenance and QC are done. Each work shift is typically 9 hours, with ~1/2 hour overlap for hand-off between shifts. The 4th shift team fills-in as needed for absent members of the other teams, for employee training, to cover vacations/holidays, and for emergencies.

This does not include non-plant employees or contractors such as crop farming and product truck drivers, security, on-farm people, specialized construction, repair and maintenance people, suppliers, waste disposal/recycle services, public relations, or regulatory compliance.

Also not included are secondary or tertiary jobs created in the nearby communities such as hospitality and food service providers, insurance, utility providers, housing and family related employment in the schools, hospitals and other public sector jobs.

For free-standing corn ethanol plants in the Midwest, the overall indirect job count has been projected to be 5X to10X the direct job count.

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James Latty (Mendota Beet Energy LLC)

Potential jobs at an energy beet to ethanol facility (size: 10-15 mg/y)

Energy-beet- to-ethanol plants in California will have a few more employees than conventional corn-ethanol plants. For each plant of the size that Mendota Bioenergy currently envisions the Daylight Shift team's employee requirements will be:

- **4 operating technicians/operators**
- **1 mechanical technician**
- **2 laboratory technicians**
- **1 clerk**
- **1 shift manager**
- **3 office staff including a bookkeeper, a shipping/receiving clerk and a plant/personnel manager**

The three non-Daylight Shift team's employee requirements will be:

- **2 operating technicians/operators**
- **1 laboratory technician**
- **1 clerk**
- **1 shift manager**

All team members will be sufficiently cross-job trained to fill-in for other operating members when needed. The total in-plant head count would be 27 people per plant.

For free-standing corn ethanol plants in the Midwest, the overall indirect job count has been projected to be 5X to10X the direct job count, or more. Therefore, **it is realistic to project that the Mendota Bioenergy whole-beet-to-ethanol business could create a total of 135 to 270 direct and indirect jobs in California's San Joaquin Valley per facility.**

James Latty (Mendota Beet Energy LLC)

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Fuel plus power, estimated jobs:

New POET cellulosic ethanol facility, Emmetsburg, Iowa-July 25, 2014. 25 mg/y; $250m Capex. **60 FTE in cellulosic facility, 40 FTE in adjacent starch facility**. **POET system recovers lignin and uses it in a boiler to make steam for both the starch and cellulosic ethanol distillation processes. An AD system is used to provide biogas to dry DDGS from the starch unit.**

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Estimated jobs and employment effects for diverse biorefineries

Company	Location	RFS	Feedstock	Capacity	Jobs announced	
	City, State			(Million gallons per year)	Biorefinery	Total potential
Pacific Ethanol, Inc	Sacramento, CA	ethanol	sorghum	200	42**	
Mendota Bioenergy	Mendota, CA	ethanol	sugar beet	1	50	350
California Ethanol and Power Project	Imperial Valley, CA	ethanol	sugarcane	66	240	1200
Canergy	Imperial Valley, CA	ethanol	energy cane	25	100	
Community fuels	Encinitas, CA	biodiesel	canola oil	21.8	34	
Bently Biofuels | Got Grease?	San Francisco, CA	biodiesel	used cooking oil		12	
Springboard Biodiesel LLC	Chico, CA	biodiesel	any vegetable or animal oil, including used cooking oil,	0.35	12	
North Star Biofuels	Watsonville, CA	biodiesel	animal fat	22.75	14	
Poet-DSM Advanced Biofuels	Emmetsburg, IA	ethanol	cellulosic and organic (corn cobs)	20		240
INEOS Bio	Vero Beach, FL	ethanol	cellulosic	8*		400
USDA & Chemtex	Sampson County, NC	ethanol	energy grasses and agricultural waste	20	65	
Dubay-Biofuels	Greenwood, WI	ethanol	waste product from cheese production	5	150	
Beta Renewables[1]	Crescentino, Italy	ethanol	cellulosic	19.8	100	300
Sapphire Energy	Columbus, NM	Green Crude	algae	15		634
FL Biofuels LLC	Lee County, FL	biodiesel	waste vegetable oil	2.1	14	
Green Energy Partners	Maribel, WI	biogas	food waste	N/A	20	

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Task 4: Economic effects: INPUT-OUTPUT Analyses to estimate jobs and economic benefits from new biorefineries in rural areas of California.

IMPLAN software consists of (1) an input-output data base; (2) several program modules for constructing inter-industry models for the user designated impact region; and (3) a model that calculates the direct, indirect, and induced effects of changes in final demand. The IMPLAN input-output data is composed of a national-level technology matrix and county-level estimates of final demand, final payments, gross output, and employment for economic sectors" Bergstrom et al. (1990)

Models' are the term in IMPLAN that identifies the analysis study area. Economic data enters the software in geographic units such as states and counties. The "Model" refers to the geographic boundaries in specific models. The economic impact is influenced by the size and economic footprint of each geographic boundary. The models are developed to measure the economic impact of each of these biorefineries within each county, i.e. in Fresno, Imperial, and San Joaquin Counties in California.

IMPLAN is widely used for estimating economic effects of new industries

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Task 4: Economic effects: Assumptions for the use of IMPLAN model for estimation of economic benefits from new biorefinery facilities that could be developed in California.

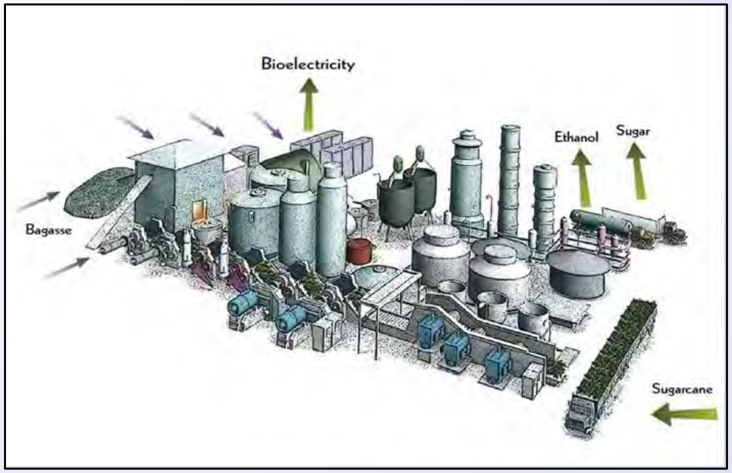
Type of biorefinery facility	Location	Feedstock	Level of feedstock (tons)	Value of Feedstock	Level of biofuel produced	Value of fuel	Co-product	Yield	Value of co-product	Construction cost (CAPEX)	Operation cost (OPEX)
Ethanol plant	Fresno, CA	Sugar beet	1,140,000	$48,279,000	30,000,000	$81,000,000	biogas	48,000 ton	$6,816,000	$38,000,000	$20,121,000
Biodiesel plant	San Joaquin, CA	Canola seed	125,000	$59,375,000	16,143,750	$65,382,188	glycerin	3,549,688 gal	$4,472,607.00	$28,628,882	$3,228,750
Ethanol plant	Imperial, CA	Sugarcane	2,700,000	$121,500,000	71,300,000	$192,510,000				$86,706,741	$1,322,508

Crop	Fuel type	Yield (as harvested)		Total CAPEX	CAPEX	CAPEX	Total OPEX	OPEX	OPEX	Total	Total	Feedstock of total
		gal/t	gge/ton	$	$/gal	$/gge	$	$/gal	$/gge	$/gal	$/gge	%
Canola	biodiesel	129.15	135.22	1791631	3.41	3.26	105000	0.2	0.19	3.61	3.45	82.5
Beets	ethanol	25.2	16.8	38000000	1.27	1.9	34440000	1.15	1.72	2.41	3.62	65.8
Sugarcane	ethanol	21.54	14.36	86706741	1.22	1.82	1322508	2.09*	3.13*	*3.30	*4.95	63.2*

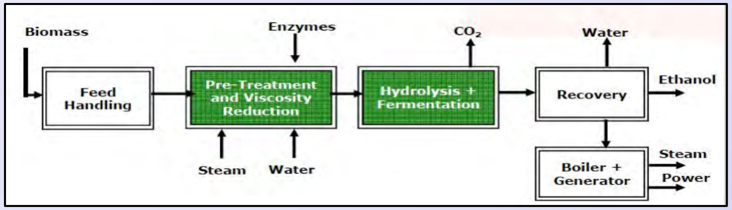
Imperial County* economic effects on principal industries affected and employment estimates for a sugarcane biorefinery

Sector	Description	Employment	Labor Income	Value Added	Total Output
9	Sugarcane and sugar beet farming	2,184.90	$30,923,115	$80,581,612	$162,732,753
36	Construction of other new nonresidential structures	505.1	$28,220,833	$37,308,853	$86,706,471
49	Beet sugar manufacturing	356.1	$22,095,605	$30,989,287	$193,625,962
19	Support activities for agriculture and forestry	142	$3,878,683	$3,780,902	$4,769,709
335	Transport by truck	80	$6,043,866	$6,987,121	$11,825,880
413	Food services and drinking places	74.3	$1,474,588	$2,451,413	$4,616,577
360	Real estate establishments	49.4	$656,627	$8,262,129	$9,832,676
369	Architectural, engineering, and related services	43.8	$2,209,986	$2,274,210	$4,686,317
388	Services to buildings and dwellings	43.4	$923,796	$1,321,075	$2,774,715
319	Wholesale trade businesses	31.1	$1,997,424	$3,995,887	$4,589,156

*21% unemployment



Modern sugarcane biorefinery



Proesa technology potentially used for energy cane

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IMPLAN model estimates for biorefinery facilities in rural California areas

County	San Joaquin	Fresno	Imperial
Model Year	**2010**	**2010**	**2010**
GRP	$21,965,310,701	$33,014,011,739	$5,320,928,974
Total Personal Income	$20,823,880,000	$28,138,740,000	$4,874,060,000
Total Employment	266,208	421,173	71,794
Number of Industries	290	296	183
Land Area (Sq. Miles)	1,399	5,963	4,175
Population	683,494	924,691	169,354
Total Households	219,157	291,553	46,678
Average Household Income	$95,018	$96,513	$104,419
Population per Square Mile	489	155	41
GRP per Square Mile	$15,700,722.45	$5,536,476.90	$1,274,474.01
Personal Income per Square Mile	$14,884,832.02	$4,718,889.82	$1,167,439.52
Households per Square Mile	157	49	11
Value Added			
Employee Compensation	$10,939,091,842	$16,480,820,749	$2,816,405,239
Proprietor Income	$2,111,388,341	$3,751,052,480	$547,103,748
Other Property Type Income	$7,230,323,165	$10,345,651,002	$1,557,092,029
Tax on Production and Import	$1,684,507,354	$2,436,487,508	$400,327,959
Total Value Added	$21,965,310,701	$33,014,011,739	$5,320,928,974
Final Demand			
Households	18,148,120,306	24,910,486,261	4,107,941,436
State/Local Government	$2,854,922,129	$4,584,847,607	$1,733,218,877
Federal Government	$1,084,032,055	$2,567,643,343	$1,016,424,422
Capital	$1,949,183,368	$4,121,478,294	$313,673,963
Exports	$14,922,949,732	$22,528,607,406	$4,062,878,606
Imports	($16,103,609,193)	($24,431,058,153)	($5,624,916,853)
Institutional Sales	($890,287,721)	($1,267,993,069)	($288,291,428)
Total Final Demand	$21,965,310,675	$33,014,011,690	$5,320,929,022

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TASK 4: Integrated Assessment- analyses included

- Identification of most likely opportunities in California for bioenergy/biofuel from agriculture (crops, marginal lands, residues)
- Economic analysis and land use (crop adoption and substitution) and location
- GHG emissions
- Likely biorefinery technology
- Jobs, regional economic impact
- **Water use, wildlife and soil erosion effects**
- **Compliance with sustainability concepts**
- Role(s) in remediation

Task 4: Environmental issues: soil erosion_several scenarios evaluated, literature for CA reviewed

Soil erosion modeling (RUSLE2):

a = r*k*l*S*c*p

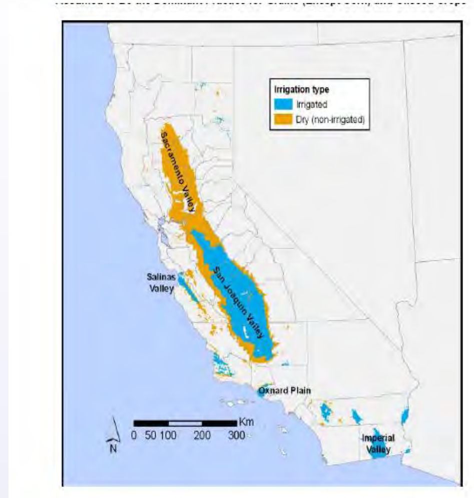
where: a = net detachment (mass/unit area), r = erosivity factor, k = soil erodibility factor, l = slope length factor, S = slope steepness factor, c = cover-management factor, and p = supporting practices f[illegible]S 2013).

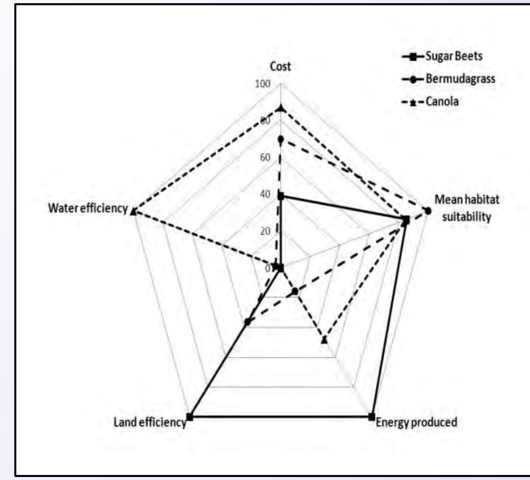
Field	Average	Soil Type	Path	Slope
Paso Robles	14 (Paso Robles, CA)	Lynne Channery clay loam	215	14
WSREC	7 (Five Points, CA)	Panoche clay loam	1,000	0.19
Western Kansas	19 (Garden City, KS)	Richfield silt loam	1,000	0.18

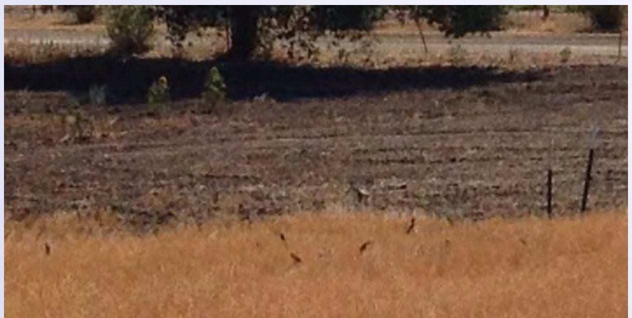
Crop Scenario	Crop Rotation Length (yrs)	Annual Soil Loss (tons/acre/year)		
		Paso Robles	*WSREC*	*Western Kansas*
Canola	2	2.1	0.021	0.23
Camelina	2	2.7	0.027	0.29
Sweet sorghum	1	-	0.066	0.48
Bermudagrass	1	-	0.0024	0.22
Sugarcane	5	-	0.0073	0.08
Orchard row middles - canola	2	7.55*	0.081*	0.41*
Barley (alt.)	2	3.3	0.031	0.25
Wheat (alt.)	2	2.8	0.024	0.2
Bare soil (alt.)	1	13	0.14	0.59

In most cases, erosion from crop production is not a significant risk in CA, but where it occurs, it adversely affects water quality with respect to sediment, pesticides and nutrients. There is no additional risk for erosion from bioenergy crop production at the scale estimated.

Task 4: Environmental effects: wildlife/invasiveness. Many species of birds and animals rely on or use crop land for all or part of their life-cycles.







Stoms et al., a&b (2012). At the scale of biorefinery development estimated, there are no significant effects on wildlife anticipated. Invasive species and invasiveness are also discussed in the report.

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Task 4: water and land use:

Under current policy and the operation of normal agricultural markets and prices, bioenergy feedstock crop production may occur in a few regions, on relatively small amounts of land and in cropping systems where the feedstock crops result in greater overall RUE, including land and water use, or provide some additional benefits to farmers not readily captured in an economic model. The scale of crop adoption for biofuel production or bioenergy is unlikely to be large in California. Realistic economic models like BCAM reflect the reality that higher value crop alternatives than most biofuel feedstocks are both numerous and preferred in most instances economically. There are no future scenarios likely in California where biofuel feedstock crops will displace food crop production in any but small amounts.

No new water use for biomass production is predicted, rather, existing water supplies are used more efficiently within cropping systems that may include small amounts of biomass for energy/bioproduct production. Concerns that bioenergy production will consume large amounts of water and displace most crops or use a significant amount of land are not meaningful in California, because they are not grounded in a realistic view of the character of agriculture in the state.

Unless public policies change in ways that artificially price fuels above food, there is no reasonable scenario that results in widespread crop displacement for bioenergy crops in California or associated water use.

Task 4: Agricultural feedstocks_Conclusions/Sustainabilty

- There are limited but real opportunities for the development of new biorefineries for fuel and power production, and for the expansion of some existing ones.
- In-state production at best will contribute to, but not be sufficient for the state's needs for alternative fuels.
- For the most part, new biorefineries could develop in the San Joaquin and Imperial Valley regions, benefitting rural areas and underserved groups.
- **There will be few, if any special, adverse effects on the state's landscape from the development of crop-based biofuels in the state, but important social benefits. California has the most advanced regulatory programs in the world focused on landscape protection. These statues, regulations, public advisory processes, incentive and enforcement programs reflect the state's consensus on what is important to protect in environmental and social areas and are characterized by political legitimacy. Nevertheless, the production of bioenergy feedstocks is anticipated to meet or exceed the general descriptions of sustainable activities found in most independent sustainabilty standards.**
- Risks to climate through indirect effects on land use elsewhere are potentially small if not positive (protective).
- Based on this analysis, policies that promote in-state development of innovative bioenergy production from agricultural sources are consistent with the state's GHG reduction goals and the public's interest in the development of a green economy.

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TASK 4: Integrated Assessment- analyses included

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- **Role(s) in remediation**

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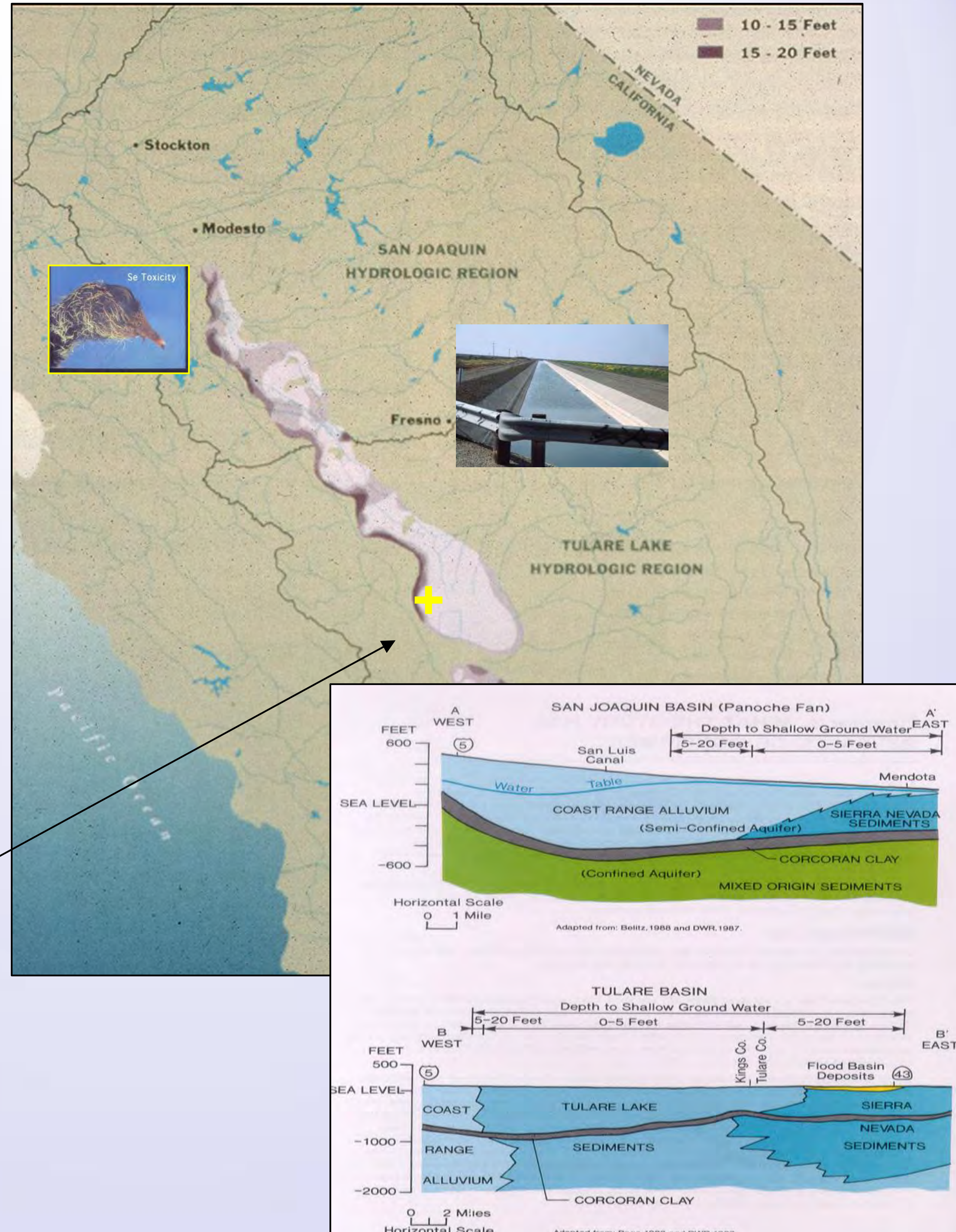
Task 4: Integrating salinity management with bioenergy production on marginal land in the western San joaquin Valley and Imperial Valley using perennial, salt-tolerant grasses as feedstocks

Taiying Zhang, Lucy Levers, Stephen Kaffka

srkaffka@ucdavis.edu

Drainage from saline, perched water tables, was a significant issue in the western San Joaquin Valley



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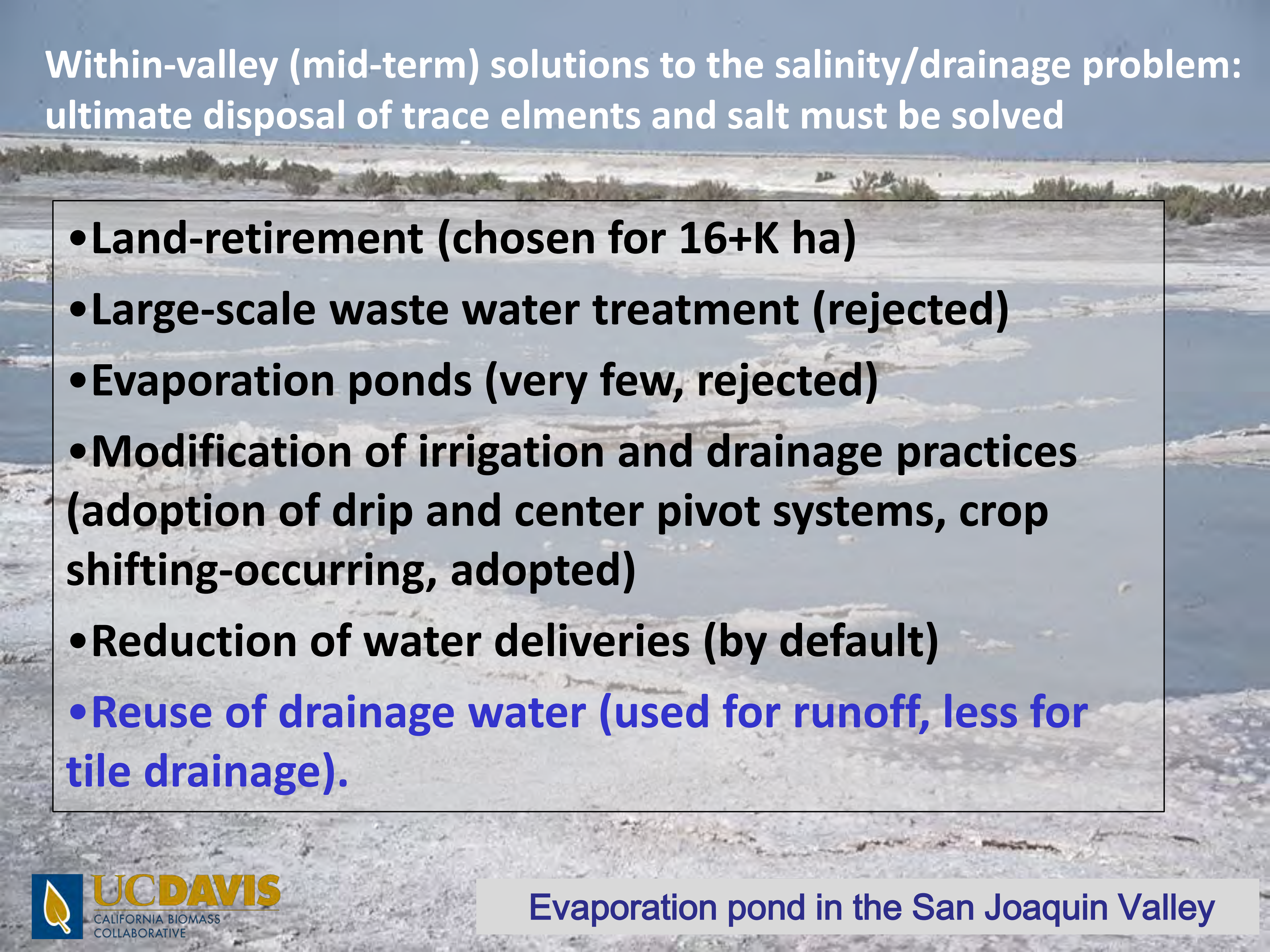
Within-valley (mid-term) solutions to the salinity/drainage problem: ultimate disposal of trace elments and salt must be solved

- **Land-retirement (chosen for 16+K ha)**
- **Large-scale waste water treatment (rejected)**
- **Evaporation ponds (very few, rejected)**
- **Modification of irrigation and drainage practices (adoption of drip and center pivot systems, crop shifting-occurring, adopted)**
- **Reduction of water deliveries (by default)**
- **Reuse of drainage water (used for runoff, less for tile drainage).**



Evaporation pond in the San Joaquin Valley

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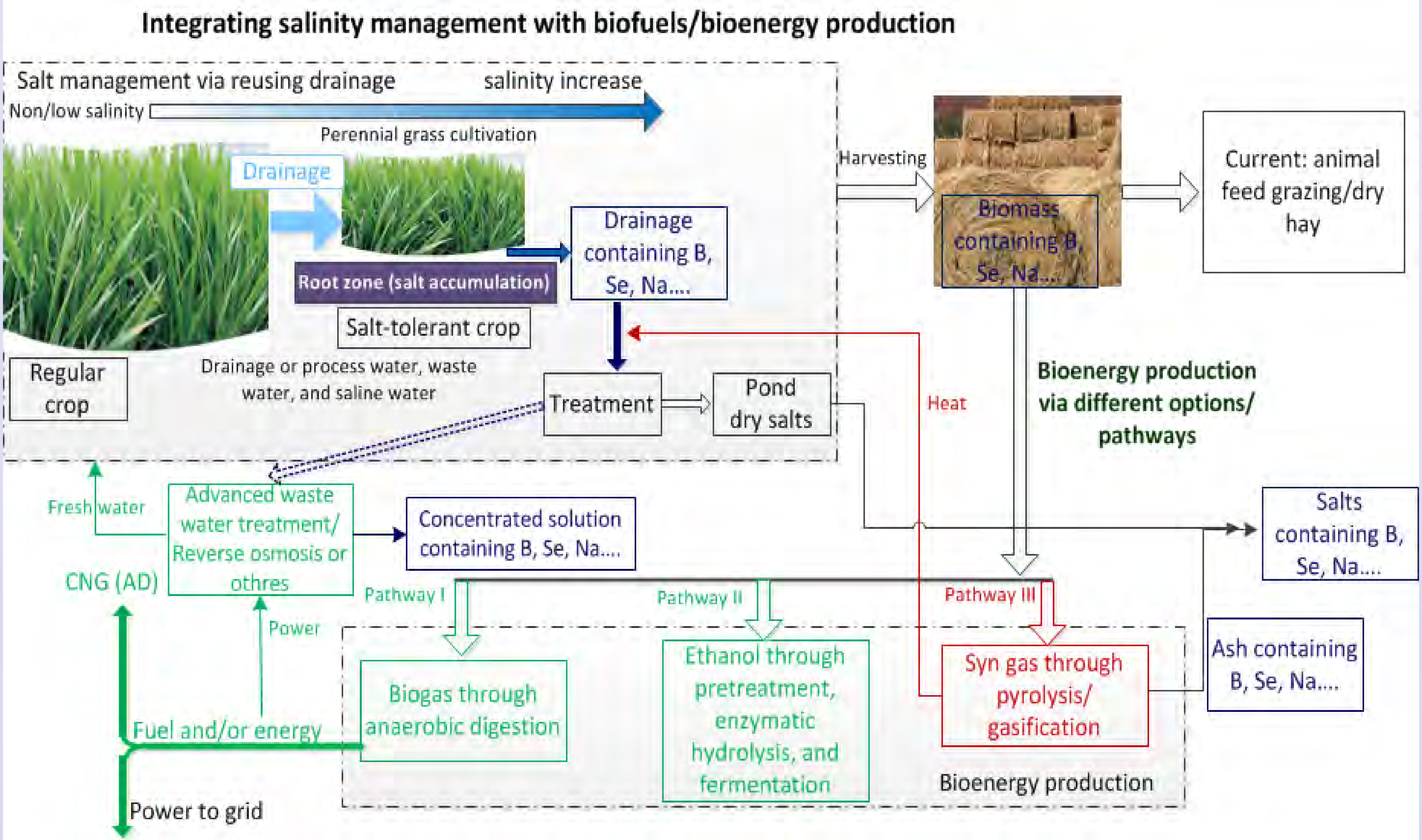
Integration Approaches



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Potential Energy production on salt-affected (marginal) lands in California

Scenario	Hectares	Plants' Needs[6]	Yield[6]	MJ[7]
San Joaquin Max[1]	700000	100%	20 Mg/Ha	$6.7 * 10^7$
San Joaquin Min[2]	80000	50%	10 Mg/ha	$3.8 * 10^6$
San Joaquin Mid[3]	300000	75%	15 Mg/Ha	$2.1 * 10^7$
Imperial Max[4]	125000	100%	20 Mg/Ha	$1.2 * 10^7$
Imperial Min[5]	50000	50%	10 Mg/ha	$2.4 * 10^6$

1: U.S. Department of Interior's estimate of the area in the SJV suitable for retirement. Wet year.
2: CA Department of Water Resources's estimate of the area with a saline groundwater table within 5 feet of the surface. Dry year, which reduces drainage impacted land and drainage water availability.
3: CA Department of Water Resources's estimate of the area with a saline groundwater table within 10 feet of the surface. Assumes a medium amount of drainage water availability.
4: Hectarage estimate is 25% of current crop acreage in the IV and 50% of the area of the Salton Sea.
5: Hectarage estimate is 10% of current crop acreage in the IV and 20% of the area of the Salton Sea.
6: As water availability increases and salinity decreases, the percent of needs increases. Dry conditions will produce less water and higher salinity, which will decrease yield.
7: Estimate of 4.75 Gj/Mg of Biomass Dry Matter-Biogas or Syngas Production.

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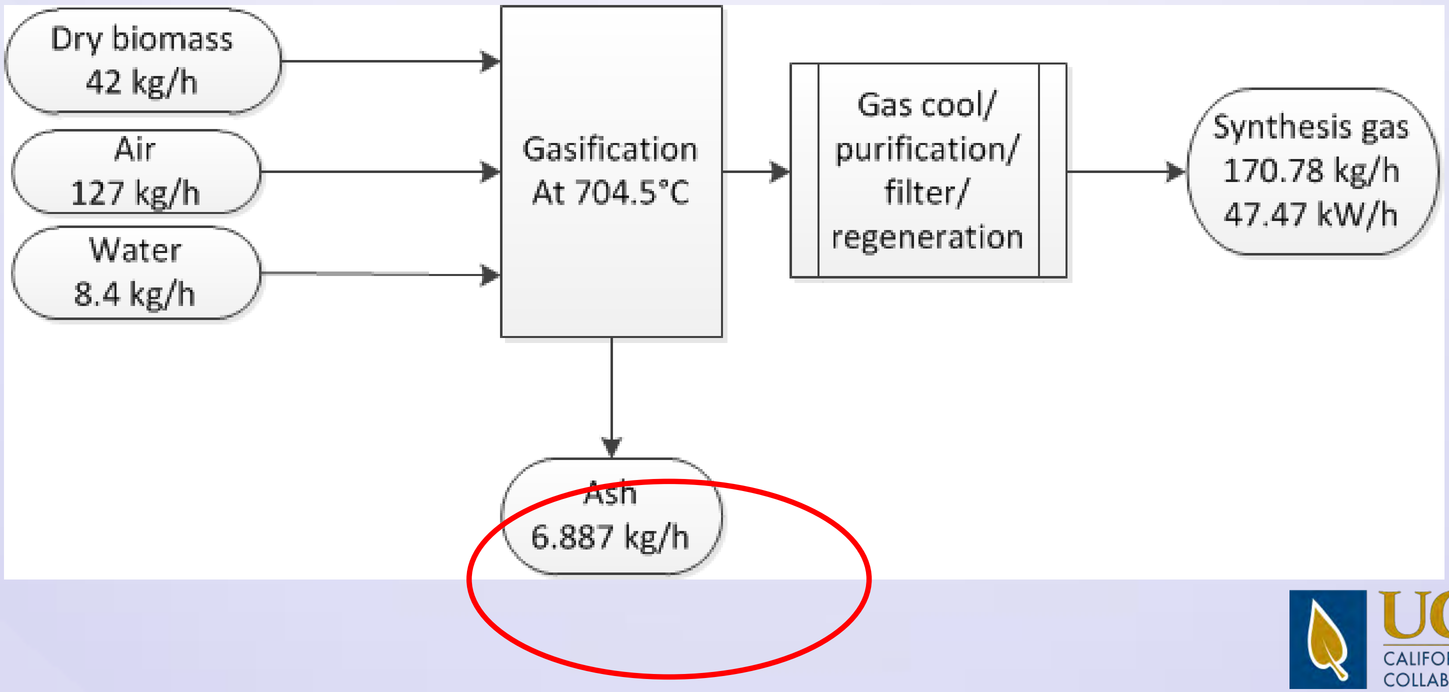
Gasification---Mass & Energy Balance

- Assumption: Grass hay = 14.0 dry MT/ha, moisture content 7.3%, ash content 12.7%.
- Gasifier: 1.0+ dry metric ton/day, 350 day/year, requiring (~350 dry MT biomass; equivalent to ~ 20 ha)
- Carbon conversion efficiency is 94.4%



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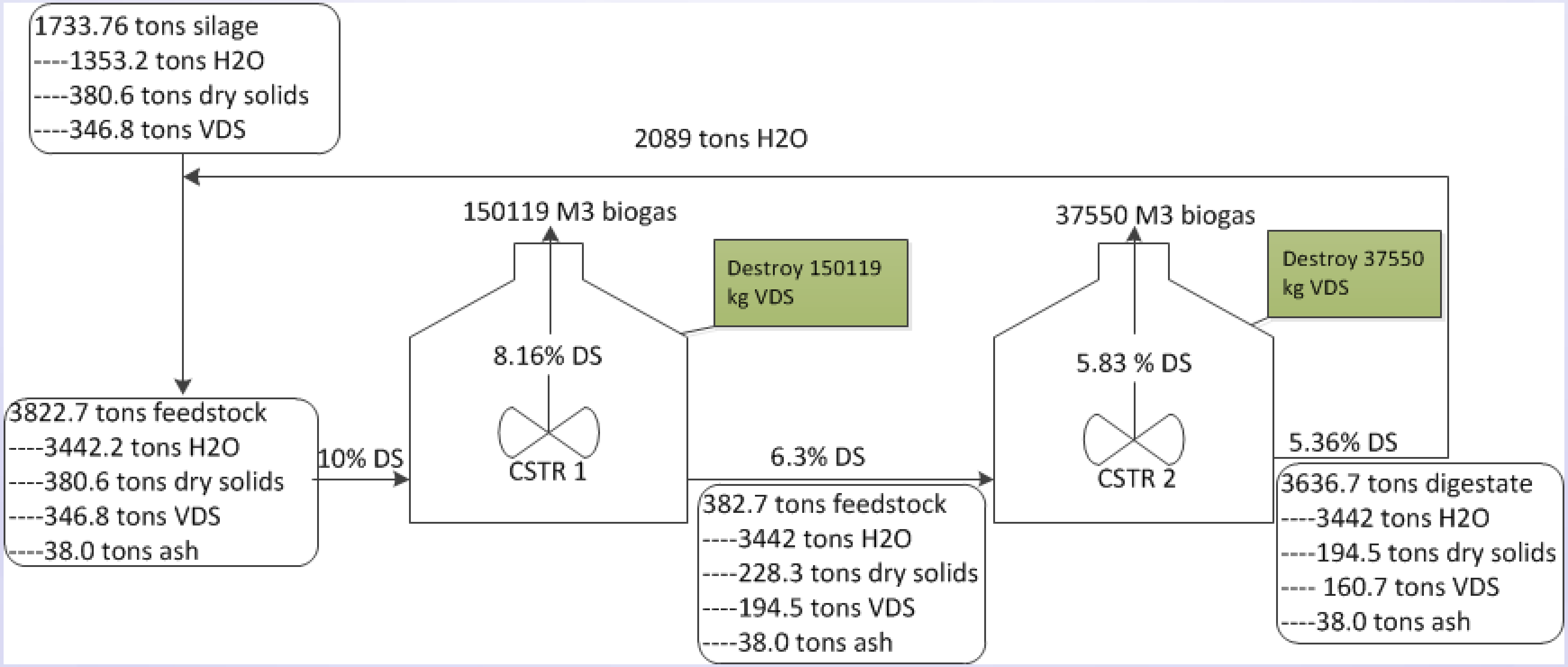
Anaerobic Digestion---Mass & Energy Balance

- Feedstock: 350 dry MT/year, 10% dry matter
- Total biogas: 37550 m^3 /year (65% methane)
- Total combustion heat: 4,441,240 MJ (~42kW)



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Summary

Different solution	Cost (2008 dollar)	Environmental impact	Energy sufficiency	Salt products
Evaporation pond	+	Toxic to wild life (?)	Energy to pump water	In the pond
Reverse osmosis	+++++*Typical 120,000 m3/day Plant- cap $160 million Capex, high opex and maintenance.	Energy + membrane replacement	Energy intensive	Brine to be disposed
Cellulosic ethanol	++++ 2,000 dry metric tons feedstock per day according to NREL with total capital cost of $515,840,000	Requires large amount additional water	Requires larger scale system	Salts and ash
Gasification	+(++) (scale and efficiency dependent; some feedstock conditioning	Compact, but air & liquid emission regulations	(From feedstock) Self-sufficient	ash
Anaerobic digestion	++(+)	Requires additional water	Self-sufficient	Salts or brine

*http://www.energyrecovery.com/swro-cost-estimator

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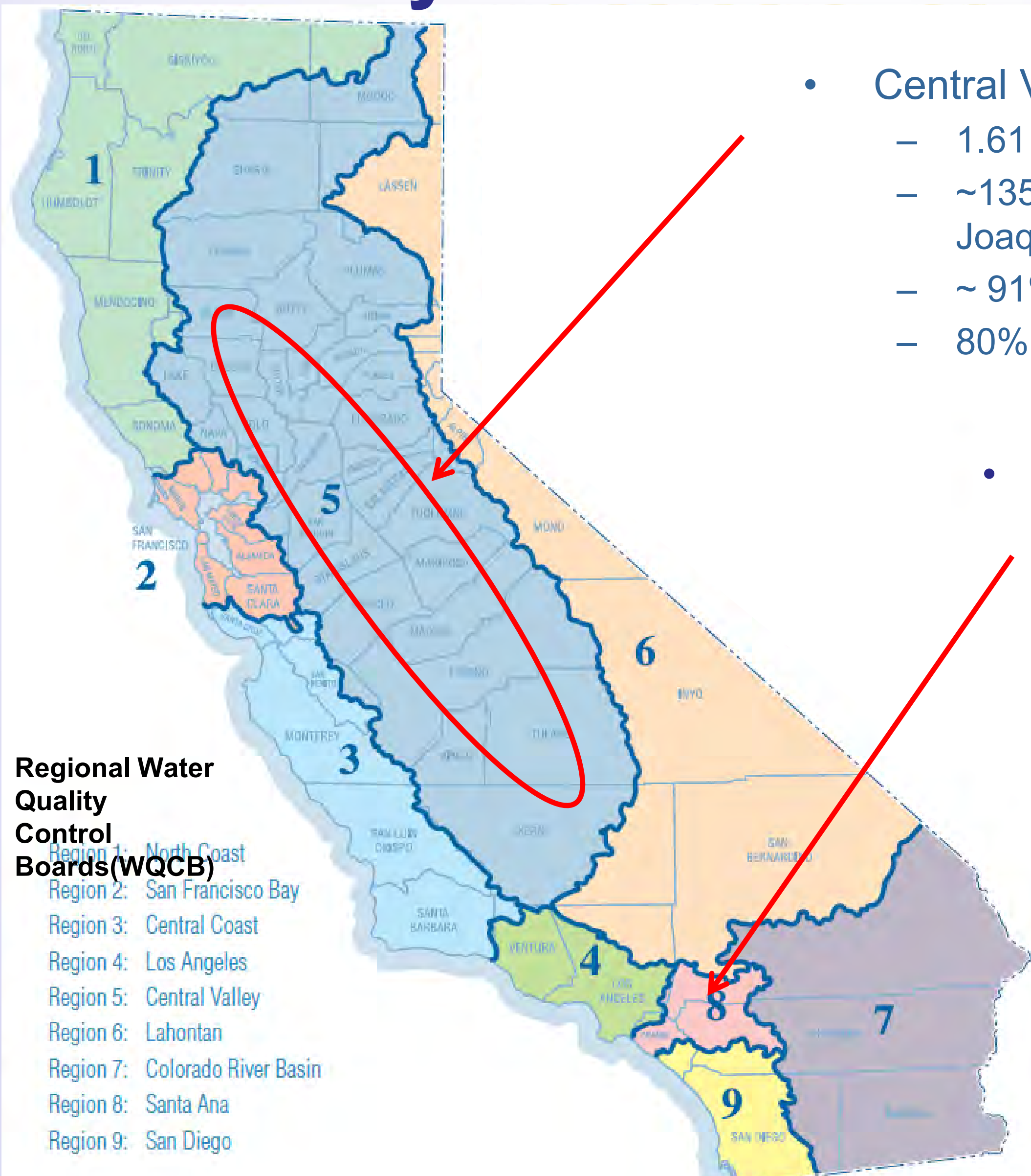
Can we link improved groundwater protection with alternative energy production and green house gas reduction?

Dairy Location and Herd Size



- Central Valley
  - 1.61 million dairy cows (milking & dry)
  - ~1350 dairies (primarily concentrated in San Joaquin Valley, or south of Sacramento)
  - ~ 91% of State's dairy cows
  - 80% of State's dairies

- Santa Ana RWQCB (essentially Inland Empire)
  - 93,500 dairy cows (milking & dry)
  - ~125 dairies
  - ~ 4% of State's dairy cows
  - 8% of State's dairies

California has
- ~ 1.78 million dairy cows
- ~ 1650 active dairies

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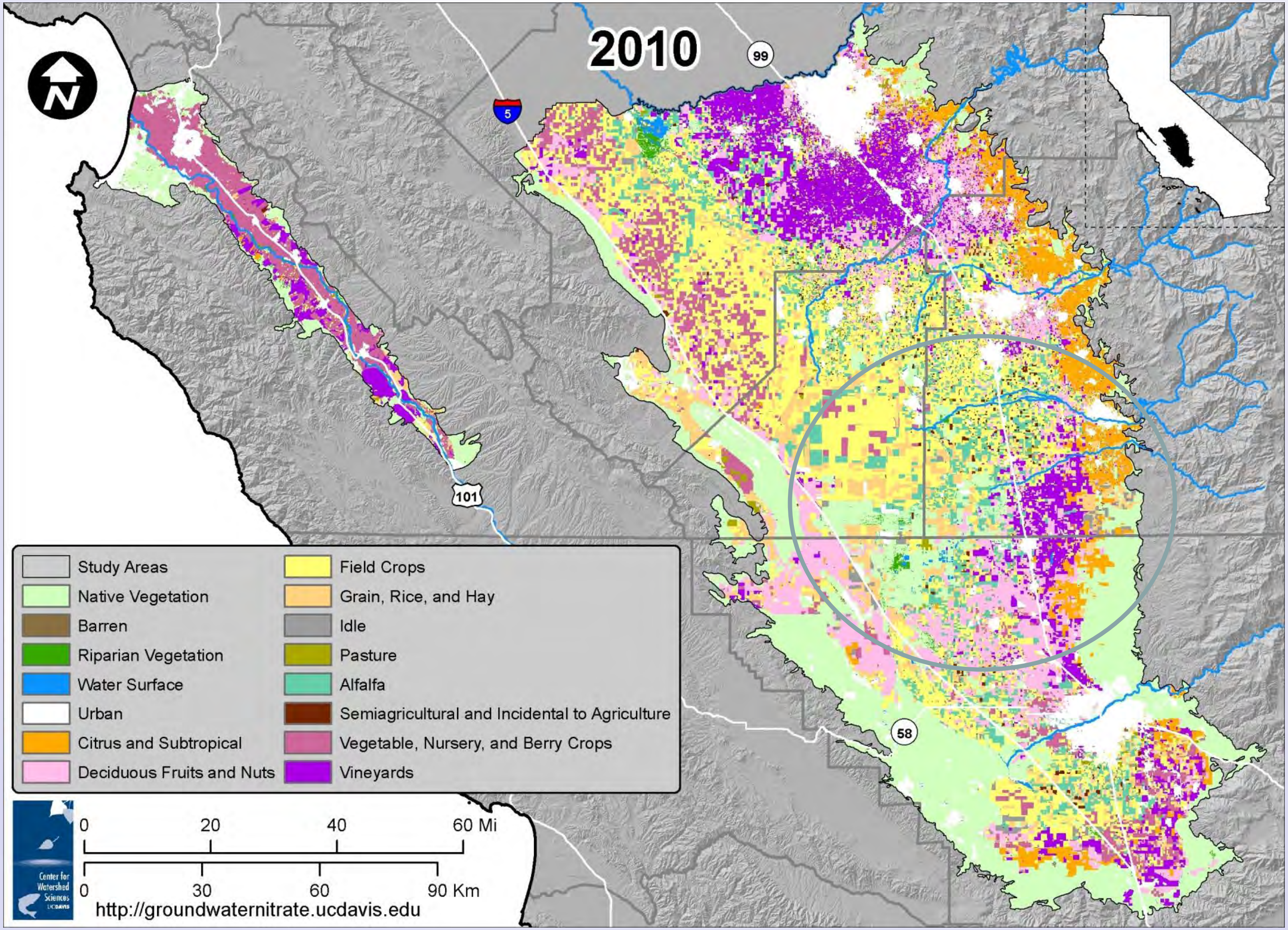
Assessing Nitrate in California's Drinking Water, With a Focus on Tulare Lake Basin and Salinas Valley Groundwater

T. Harter and J. Lund, et al., 2012.
Center for Watershed Sciences, UC Davis
http://groundwaternitrate.ucdavis.edu

Agricultural Sources



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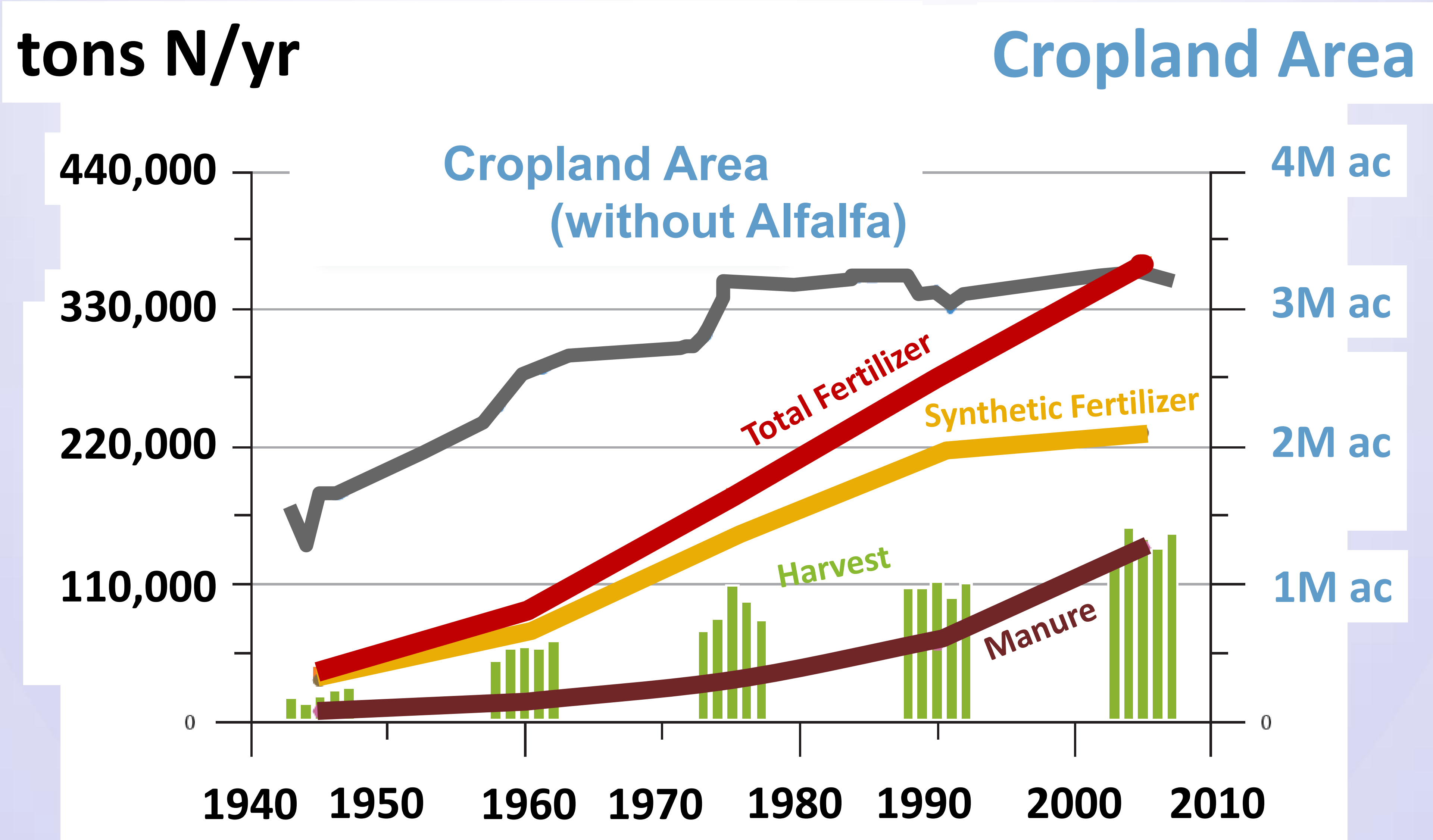
Historic Nitrogen Fluxes



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Dairy manure: low solids/high water content, large volume of water must be managed.

But it is a consistent, year-round large supply of potential energy and nutrients (11.5 m dry t/y)

Typical Composition of Liquid and Solid Effluents

Liquid Byproduct

	Concentration (mg/L)
Total Solids	10,000 – 20,000
Suspended Solids	4,000 – 6,000
Dissolved Solids	6,000 – 14,000
BOD	5,000 – 15,000
Ammonia	**1,000 – 3,000**
Phosphorus	**1,000 – 10,000**
Potassium	**5,000 – 15,000**
Sodium	**1,000 – 3,000**

Zhang, 2012

Solid Residuals (Press Cake)

	Composition (dry basis)
Total Solids	30 - 40% (Wet Basis)
Moisture	60 – 70% (Wet Basis)
Nitrogen	**1 – 5%**
Phosphorus	**0.2 – 1%**
Potassium	**0.2 – 1%**
Sulfur	0.1- 0.3%
Magnesium	0.1 – 0.2%
Calcium	0.5 – 1%
Sodium	0.2 – 0.8%
Copper	10 – 100 ppm
Iron	200 – 1,500 ppm
Manganese	30 – 1,000 ppm
Zinc	100 – 1,000 ppm

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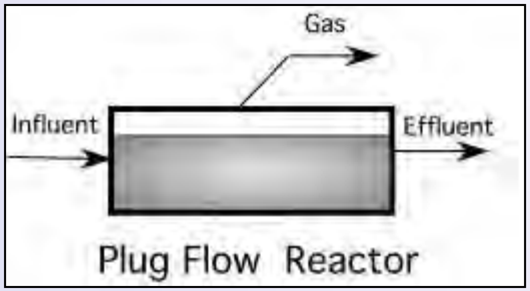
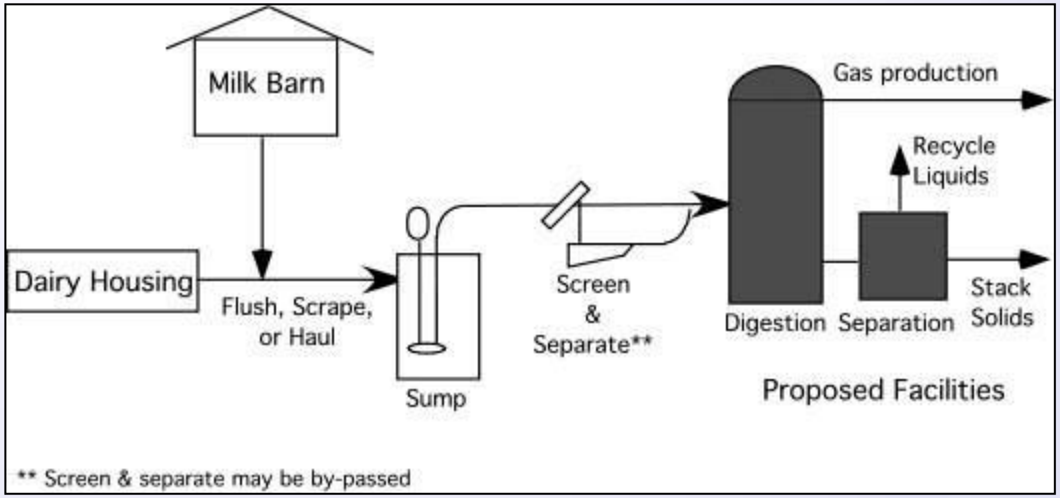
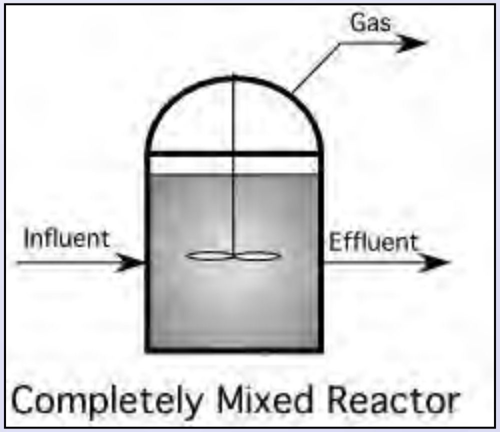
Anaerobic Digesters





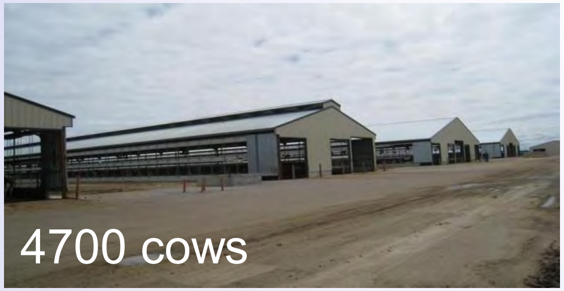
Different manure handling systems, and digester designs, result in different effluent characteristics and lend themselves to different post-digester effluent processing systems.

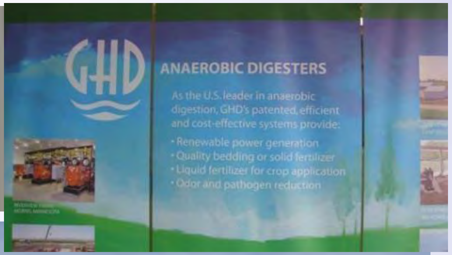
But AD systems do not affect the amount of nutrients that must be managed.



Also, it is more difficult to manage organic N precisely than fertilizer N.

Energy production via anaerobic digestion:
Solid-liquid separation to produce fibrous solids for animal bedding, soil amendments (compost) or other fiber products, plus
Nutrient separation and concentration to produce effective fertilizer products that can be economically used and transported.





System Design: DVO, Inc.
Man. & Installation: Andgar Corp.
Developed by AgPower Partners
Biogas Used for Electricity

Co-digestion

3. Chemical flocculation and press for fine particles

2. Medium size particles

1. Coarse solids removal

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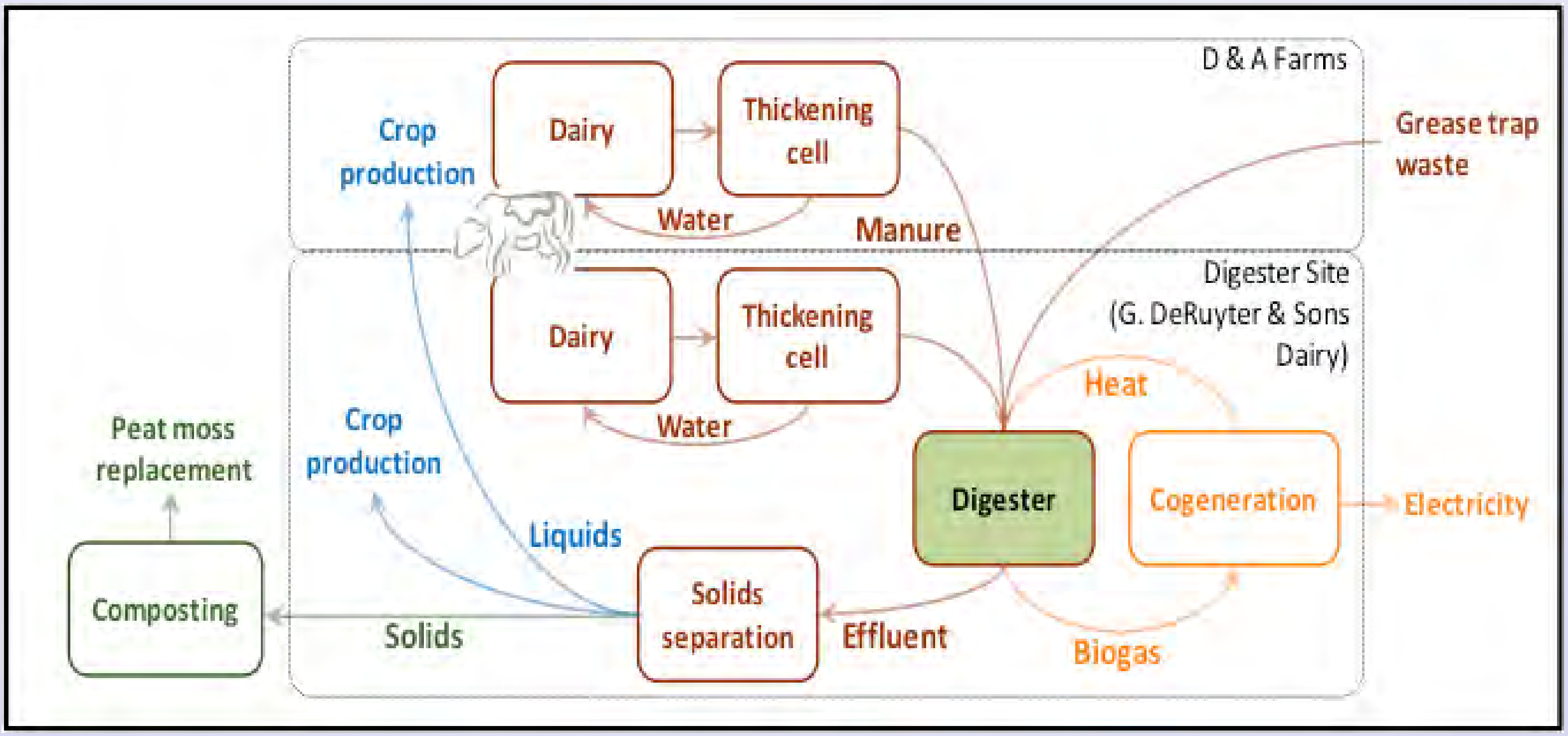
Schematic of one possible set of pathways for nutrient removal from a Washington State Dairy

(Nutrient recovery targets: 70% NH_3, 80% P, 20% K).



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C. Frear (Washington State University); EPA Technology Market Summit, Washington DC, May 14, 2012

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1. Use of marginal land for power and fuel production in California. ***Can bioenergy production facilitate ultimate management of trace elements and salts in the western San Joaquin Valley and the Imperial Valley?***

2. Bioenergy from anaerobic digestion of manure: ***Can bioenergy production help protect groundwater in regions with large numbers of dairy farms?***

3. Bioenergy from woody biomass: ***Can the use of woody biomass for bioenergy help maintain forest health and reduce risk and losses from wildfire, and protect watersheds?***

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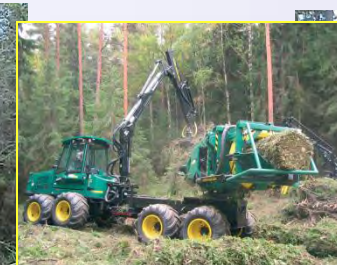
TASK 4/(3): Woody Biomass for Energy in California

The objective is primarily to create 'sustainably managed woodsheds and other biomass production regions' that will support the sustainable management of urban interface woodlands and forested lands to reduce fuel loading and the potential of uncontrolled wildfire. The use of biomass and residues from forest management/products to produce bio-energy and bio-products and to stimulate local economic activity and long-term stability is a means to that larger end.



Warming and Earlier Spring Increases Western U.S. Forest Wildfire Activity

A. L.Westerling,[1,2]* H. G. Hidalgo,[1] D. R. Cayan, [1,3] T. W. Swetnam[4] [1]Scripps Institution of Oceanography, La Jolla, CA 92093, USA. [2]University of California, Merced, CA 95344, USA. [3]US Geological Survey, La Jolla, CA 92093, USA. [4]Laboratory of Tree-Ring Research, University of Arizona, Tucson, AZ 85721,USA. Science Express, July, 2006

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Bioenergy from Forest Woody Biomass

What is the effect of forest management and policy on woody biomass availability for the bioenergy industry in California?

What are the optimal locations and size of potential biorefineries based on forest biomass feedstock supply chain optimization?

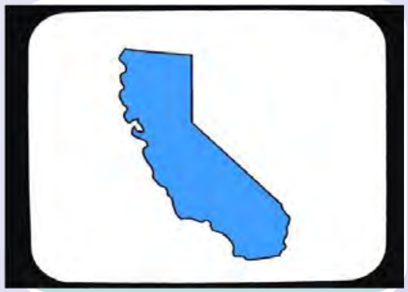
A spatially explicit modeling approach:

1. Potential forest residuals resource assessment using **BioSUM 5.2** model developed by USDA Forest Inventory Analysis (FIA) unit and co-developed for California by UC Berkeley.

2. Optimal siting and size of biorefineries in CA using the **Geospatial Biorefinery Siting Model (GBSM)** developed by UC Davis.

USDA FIA
BioSUM 5.2

UC Davis
GBSM



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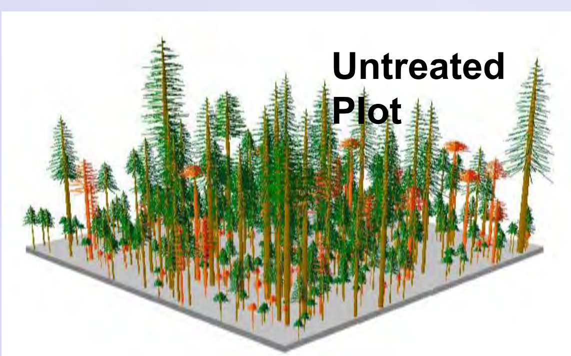
BioSUM 5.2

BioSUM 5.2 is a spatially explicit dynamic forest modelling framework based on USDA FIA stand-level data that

- simulates forest growth, wildfire disturbance regimes, and the harvest of timber and residual woody biomass
- applies multiple management prescriptions
- optimizes for chosen policy scenarios

Example of management prescriptions (courtesy UCB, B. Sharma, W.Stewart)

PGK_1	**Thin on Year 0 and 20 to a target residual basal area of 75 sq. ft. Prefer WF for removal. Thinning is limited to trees of size 4 -36 inch. Thinning occurs uniformly across DBH range. Merch. limit is 7" default. Surface fuel treatment (prescribed burn) occurs in the year of thinning.**
PKG_2	Thin on Year 10 and 30 to a target residual basal area of 75 sq. ft. Prefer WF for removal. Thinning is limited to trees of size 4 -36 inch. Thinning occurs uniformly across DBH range. Merch limit is 7" default. Surface fuel treatment (prescribed burn) occurs in the year of thinning.



After Canopy Density Reduction Treatment
Residual BA=125 sq ft/ac

BioSUM 5.2

Example of policy scenarios

Each scenario provides output datasets of woody biomass quantity and distribution for input to the GBSM model.

1. *No treatment (reference case):* establish a comparison of the extent of forest growth without management and the extent and severity of fires without treatments.

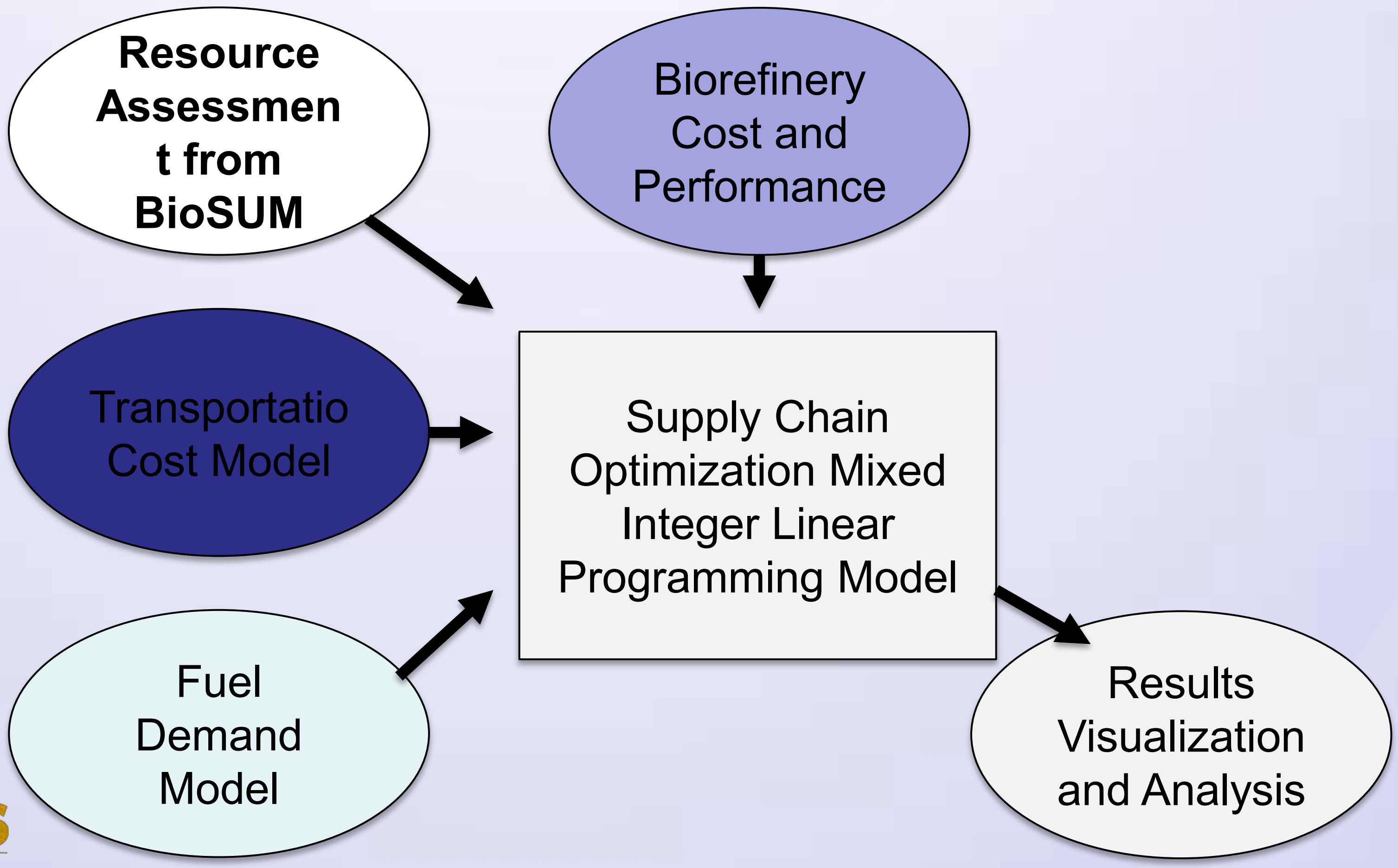
2. *Maximize woody biomass production*: a hypothetical scenario in which forests are managed prioritizing residual biomass and bioenergy.

3. *Minimize stand-replacing wildfire risk*: a realistic scenario in which hazardous fuel reduction is prioritized as a forest management goal.

4. *Minimize merchantable timber removal*: a “conservative” scenario in which medium and large trees are left in place.

GBSM Modeling Approach

The Geospatial Biorefinery Siting Model (GBSM) is a supply chain optimization model that determines optimal locations and size of potential biorefineries.



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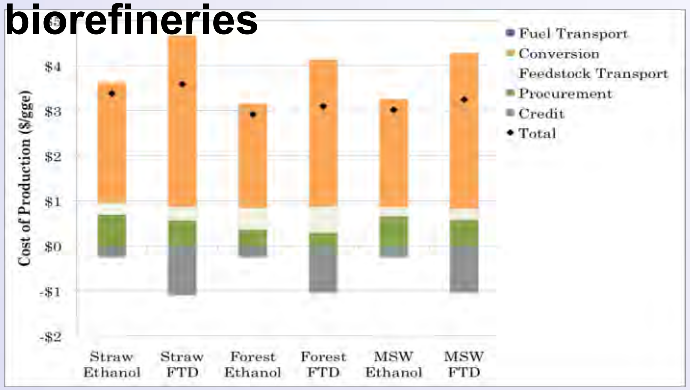
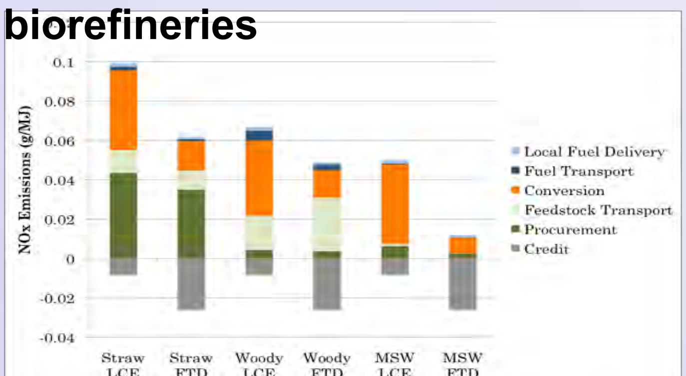
Sample Results
BioSUM and GBSM

What are the optimal locations and size of potential biorefineries based on forest biomass feedstock supply chain optimization?

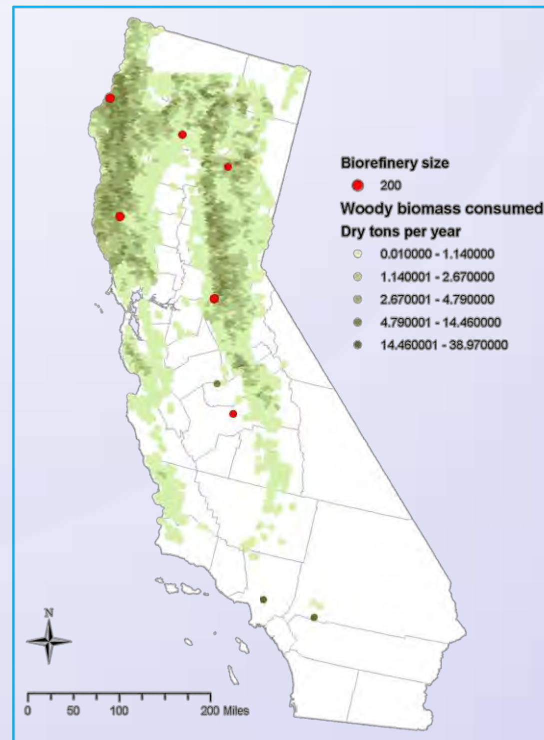
Breakdown of costs for optimally sited biorefineries



Breakdown of Nox emissions for optimally sited biorefineries



Example of optimal biorefinery locations



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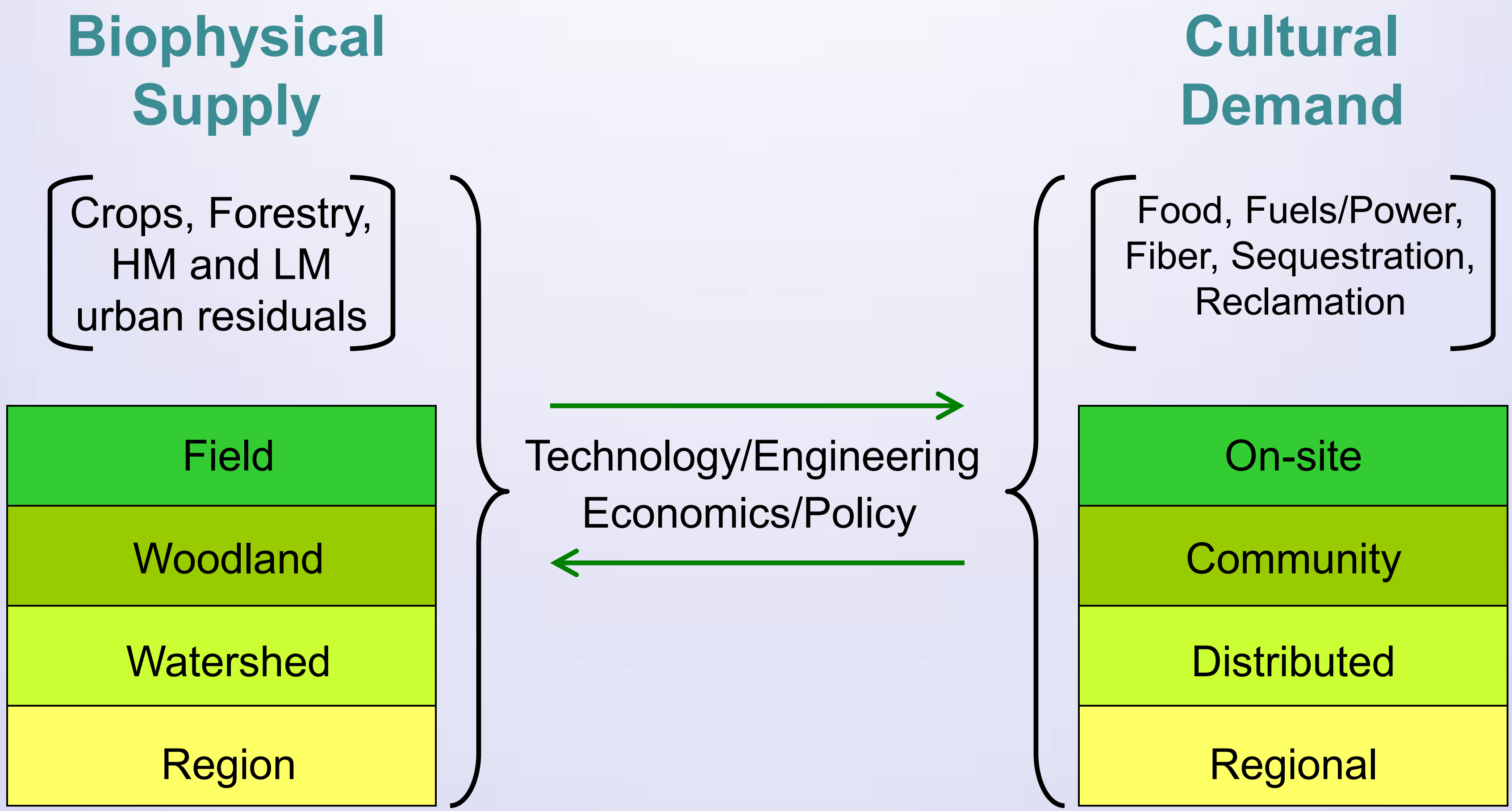
An Integrated Biomass Assessment Model:
Balancing Biomass and Carbon Resources



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Biomass/MSW Gap Assessment and Technology Options for Biogas Clean-up

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Steve Kaffka
Rob Williams

Task 6. Biomass/Municipal Solid Waste Technology Gap Assessment

Draft Report Fall, 2013

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Biomass Conversion Pathways

- Thermochemical Conversion
  - Combustion
  - Gasification
  - Pyrolysis
- Biochemical
  - Anaerobic / Fermentation (anaerobic digestion)
  - Aerobic Processing (composting)
- Physicochemical
  - Heat/pressure/catalysts
    - Hydrotreating/Cracking/Refining

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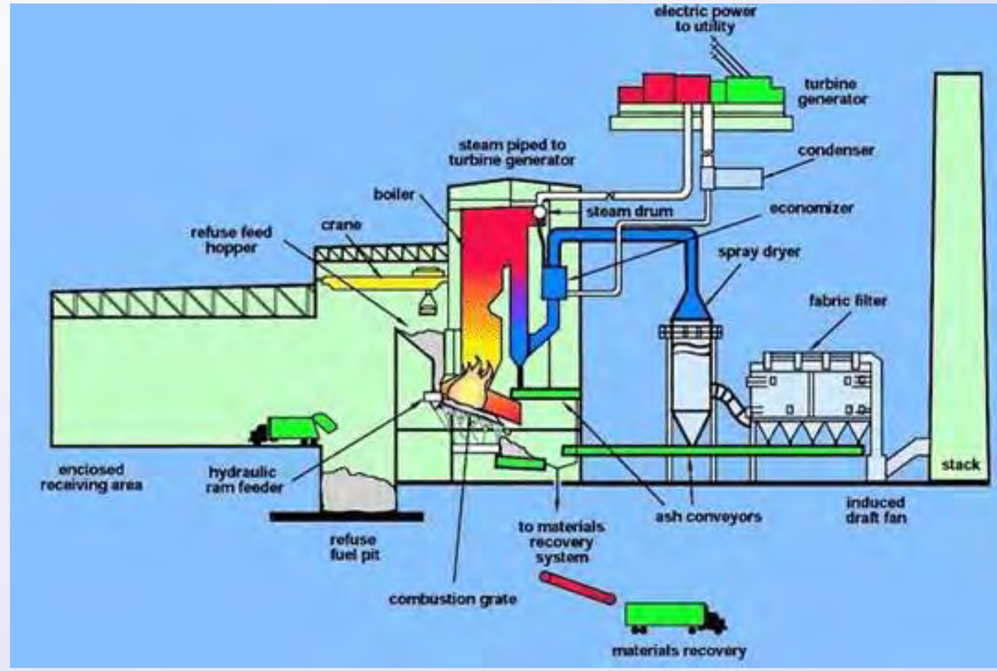
Survey of MSW Conversion Options

Combustion Systems

- Some 800 solid fuel MSW combustion systems worldwide (3 in CA)
- 195 million tons per year combined capacity
- Vast majority are solid-fuel grate-fired technology



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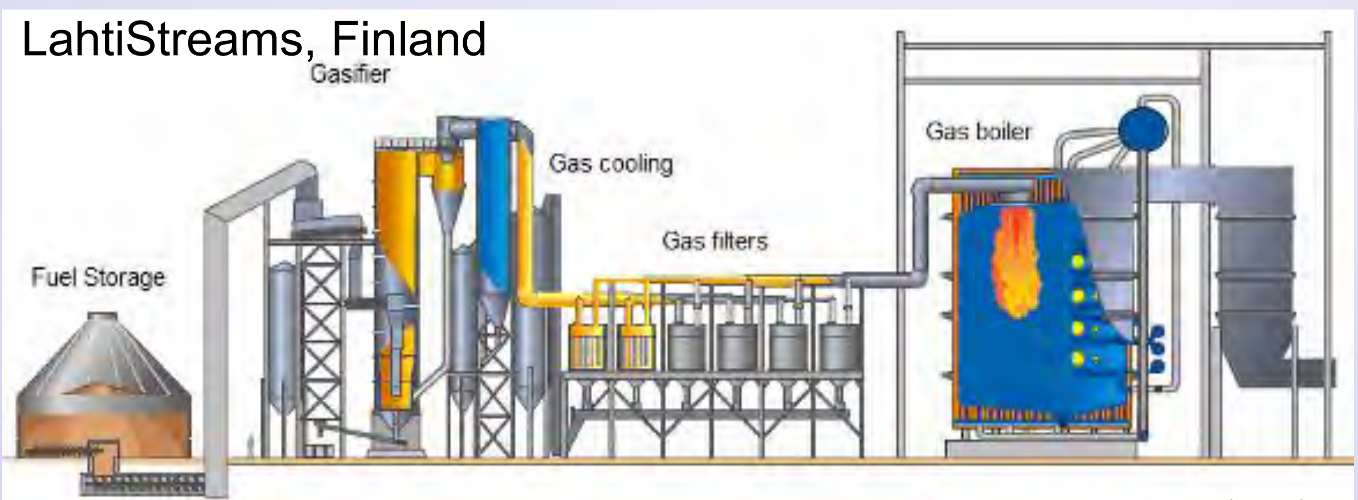
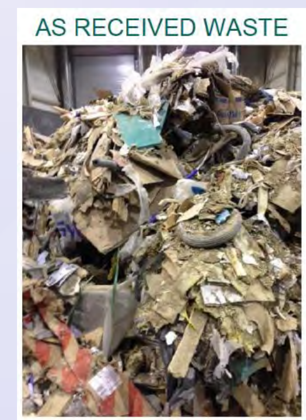
Survey of MSW Conversion Options

Gasification of MSW

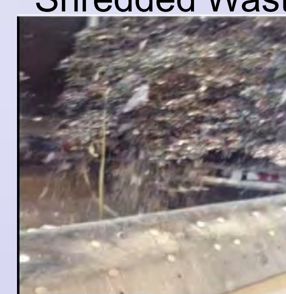
- ~ 100 gasification facilities worldwide consuming some kind of waste or MSW material
  - Most operate as close-coupled combustion ("two-step oxidation") but
  - advanced systems in development



Bill Partanen, Metso (2013)



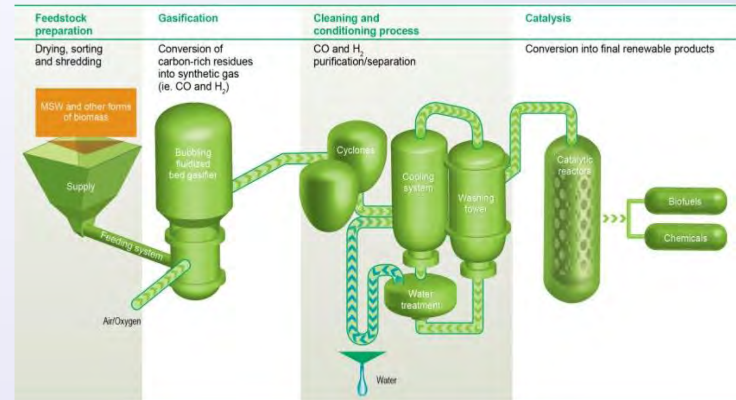
Shredded Waste



Survey of MSW Conversion Options

Enerkem MSW Gasification-to-Ethanol

- Commissioning - Edmonton, Canada
- 110,000 t/y refuse derived feedstock
- 10 million gallons/y ethanol capacity



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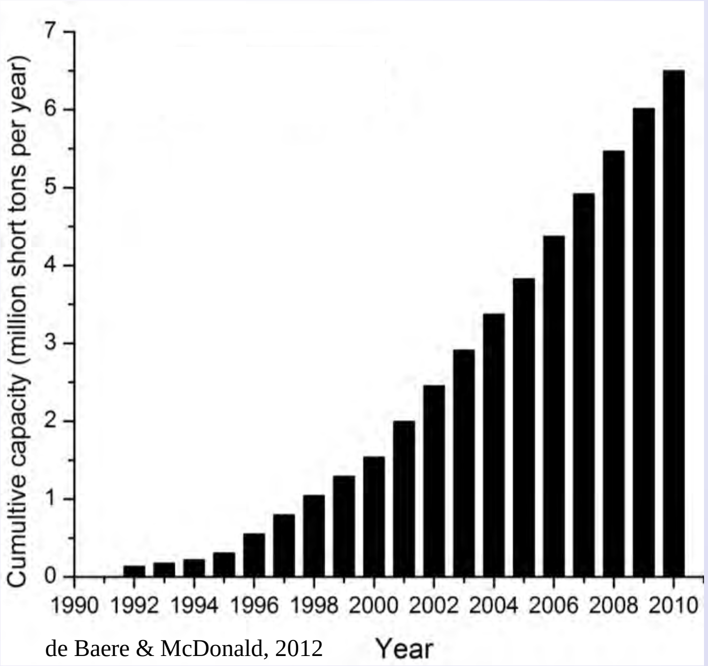
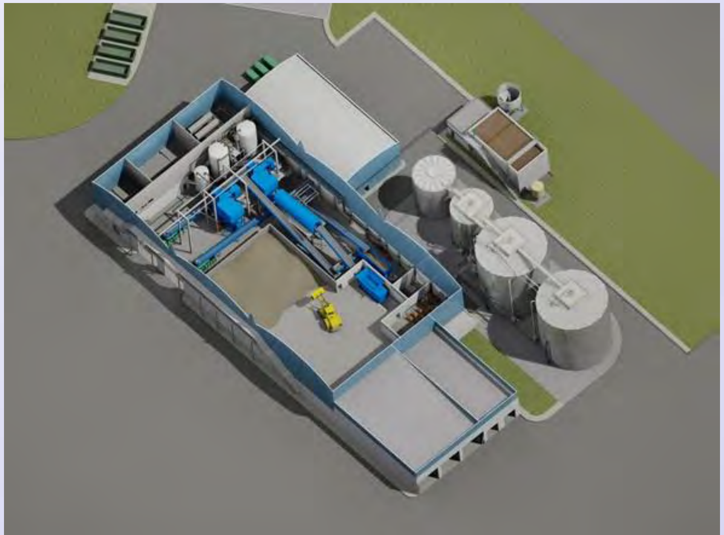
Survey of MSW Conversion Options

Anaerobic Digestion of MSW (or components)

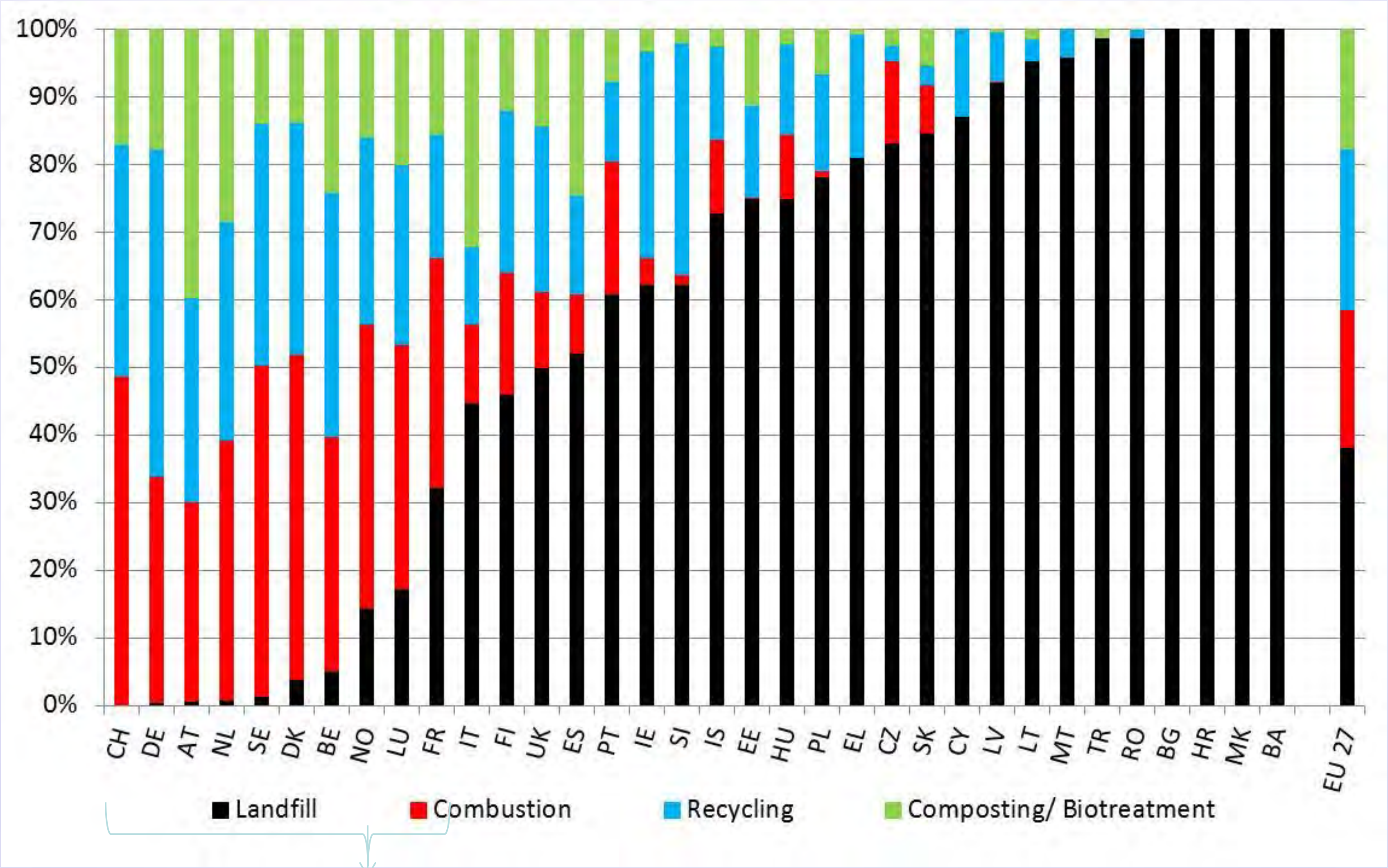
- Installed capacity > 6 million tons/year (mostly in Europe)

- 5-10 operating / commissioning / design stage in California





Disposition of MSW in Europe

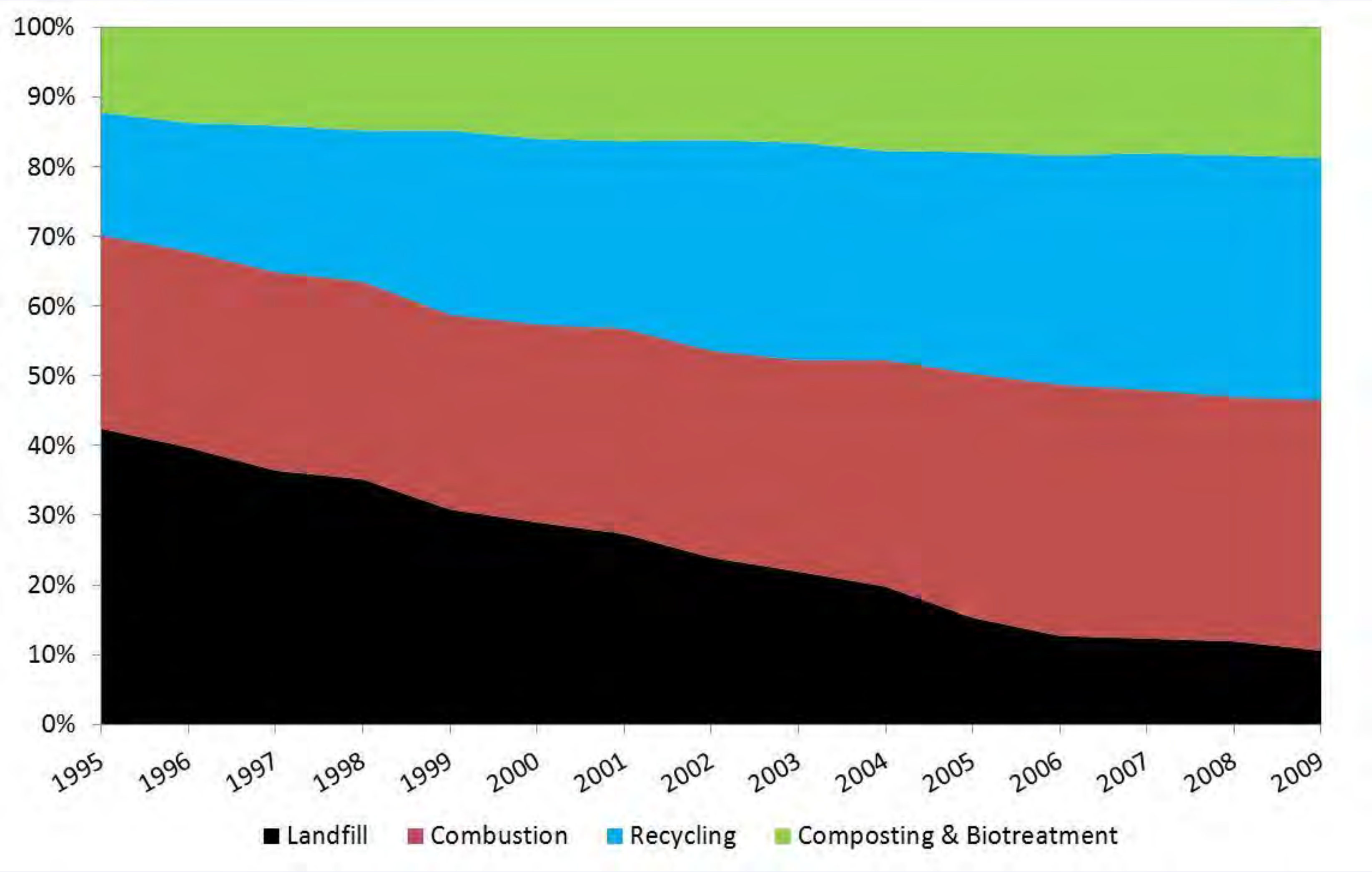


Group 1: 10 lowest landfill rates

Group 1: Switzerland, Germany, Austria, Netherlands, Sweden, Denmark, Belgium, Norway, Luxembourg, France

Eurostat (2011)

MSW Treatment trend; Group 1 countries in Europe*



* Group 1: Switzerland, Germany, Austria, Netherlands, Sweden, Denmark, Belgium, Norway, Luxembourg, France

Eurostat (2011)

Task 6 Conclusion

- Combustion, anaerobic digestion, and to some extent gasification, are solid waste treatment methods used throughout the world, especially Europe where
  - Landfill bans exist or land is scarce
  - Disposal Costs are high (> $100 / ton)
- Technologies meet stringent local environmental regulations in Europe and Japan
- EU countries with high recycling rates burn non-recyclable material for energy rather than landfill
- Waste management policy in California prioritizes source reduction and recycling/reuse as does the US EPA and the European Union
- Unlike the EU or the EPA, California policy does not recognize energy recovery from MSW conversion (thermal methods) – Thermal Conversion with Energy Recovery is the same as landfilling with respect to diversion accounting / RECs

Task 7. Biomass Gasification Technology Assessment

- Task is still in progress
- Update of current activities
  - Including work on advanced gasification scenarios (Task 5 and other CEC projects)

Task 7. Biomass Gasification Technology Assessment

List of instate gasifier activities (partial list shown)

Name	Location	Type	Application	Comments
Phoenix Energy	Merced	Downdraft	Electricity (Engine)	Not sure if operating! Ankur design gasifier. ~ 500 kW (4000+ $/kW estimated capital cost) Loan gurantee from CA Waste Board
Phoenix Energy	Oakdale	Downdraft	Electricity (Engine)	Commissioning/ Not Operating?! . Ankur design gasifier. ~ 1 MW (Central Valley Ag. Grinding)
Community Power Corp.	Winters, CA	Downdraft	Electricity (Engine)	Demo at Dixon Ridge Farms (walnut shell fuel) 50 KW unit has several thousand hours of operation. 100 kW unit installed Fall 2012 (50 kW unit idle)
Pro-Grow Nursery	Etna, CA	Downdraft	Burner fuel (+ engine generator)	Development project. 1000 + hours operation. Now developing a "linear hearth" downdraft gasifier for increased capacity (maintaining 'low-tar' geometry). Replace propane for greenhouse heating. Fluidyne gasifier (Doug Williams, New Zealand) ~ 100 kWe
Cabin Creek	Truckee, CA	not specified	CHP	Placer County ~ 2MW biomass project. Phoenix Energy is developer. Believe searching for technology othr than Ankur.
North Fork	North Fork, CA	not specified	CHP	Phoenix Energy is developer. Believe searching for technology othr than Ankur.
Sierra Energy	McClellan, CA	Updraft	Electricity & Fuels	Had PDU at McCllelan. Large grant from CEC for Port of Sac. Federal project at Hunter Liggett
West Biofuels	Woodland, CA	Dual Fluidized Bed (indirect gasifier)	Syngas to liquid + engine generator	5 ton/day, Research and Demo (UC San Diego, Davis, Berkeley). Several Grants supporting work. Adapting the Gussing Austria gasifier system. Building INSER "Circle Draft" gasifier
Adaptive Arc		Downdraft / Plasma assist	CHP	Demo facility at UC Riverside
Humboldt State	Eureka, CA	not specified	Hydrogen to fuel cell / mobile systems	Biomass gasifier to fuel cell application w/ Blue Lake Rancheria. Also, large DOE grant to look at mobile conversion systems for in forest material
UC Davis	Davis, CA	Lab Fluid Bed	Feedstock / syngas research	Professor Jenkins' Lab. Collaboration with West Biofuels/ UC San Diego
UC Riverside		Hydrogasification		CEC funding

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Task 7. Biomass Gasification Technology Assessment

Collaborating with Watershed Research and Training Center and the Biomass Energy Resource Center (BERC) to generate database of gasification vendors

- ~ 85 listings - worldwide
- Attempt to vet entries,
- Determine actual operating experience or operating facilities

Manufacturer	m	Min	SingleUnitMa	MoreInfo	Location	ConversionTechnology
ArboElectroGen	Chips	30 kW	800 kW	http://www.arborhp.com/home	Stamford, Lincolnshire,	Down-draft gasification to IC
3i Energy System	Chips	5KWe		http://www.3ienergysystem.com/general.html	Barre, Vermont	Down-draft gasification to IC
A.H.T. Pyrogas	Chips,	80 kWe	1MWe	http://www.aht-pyrogas.de/en/gasification-	Bergisch-Gladbach	Both down and up draft
Adaptive Arc	Chips, Pellets			http://www.adaptivearc.com/	US	Plasma assist gasification
Advanced Gasification Technology	Chips	350 kW		http://www.agtgasification.com/eng/prodotti_agt.htm	Arosio, Italy	Down-draft gasification to IC
Agnion	Chips, Pellets	~ 40 kW	3 MW	http://www.agnion.de/en/	Germany	In-direct steam gasification
All Power Labs	Chips	10 kW	20kW	http://www.gekgasifier.com/	California	Gasification
Alternative Energy Solutions	Chips, Pellets	.03	20 MMBTU/hr	http://www.aesintl.net/technologies/modular-biomass-	Kanas	
AlterNRG Westinghouse Plasma		50MW		http://www.westinghouse-plasma.com/projects/	Pennsylvania, USA	Gasification
Andritz Carbona	Pellets	6MWth	200MWth	http://www.andritz.com/pp-gasification-andritz-carbona	Austria	Gasification
Ankur Scientific	Chips	5kW	850kW	http://www.ankurscientific.com	India	Gasification to IC engine
Arbor Electro Gen	Chips	30kW	800kW	http://www.arborhp.com/heat-and-power-	UK	Gasification
Aruna Electrical Works	Chips	10kWe	5MW	http://www.arunaelectricalworks.com/biomass/BiomassGa	India	Gasification
Associated Physics of America	Chips	N/A	N/A	http://www.associatedphysics.com/ProdServices/Gasificati	Mississippi	Gasification
Babcock & Wilcox Voland	Chips	1MW	3.5MW	http://www.volund.dk/		Updaft gasifiaction
Bellweather				http://www.bgt-online.eu/index.php?lang=english	Hennigsdorf, Germany	Gasification
Biogen		200kW	700kW	http://www.biogendr.com	Miami, Florida	Gasification
Biogreen	Chips			http://www.biogreen-energy.com/applications/biomass-	France	Torrification and Pyrolysis
Bioliq		2 MW		http://www.bioliq.de/english/67.php	Germany?	Gasification to Fisch-Troph
Biomass CHP	Chips	200 kW	300 kW	http://www.biomasschp.co.uk/index.php	UK	
Biomass Engineering Ltd	Chips	250 kWe	1 MWe	http://www.biomass.uk.com/		
Bioneer Oy		5 MW th			Finland, Sweeden	
Bioresidue Energy Technologies Ltd	Chips	19kW	1200kW	http://betpl.net/home	India	Gasification
Carbo Consult and Engineering	Pellets	50kVA	400kVA	http://www.carboconsult.com/	South Africa	Gasification
Chalmers		2 MW	4 MW	http://www.chalmers.se/en/areas-of-	Goteborg, Sweeden	
Chandurpur Works		35kWe	500kWe	http://www.chanderpur.com/project-executed-client-	India	Gasification
Chiptec	Chips,	N/A	N/A	www.chiptec.com/chiptec_website_nextgen_002.htm	Williston, VT	Combustion
Choren		45 MW th		www.choren.com	Friedbergy, Germany	
Community Power Coproration	Chips	25 kWe	100 kWe	http://www.gocpc.com/		Gasification to IC engine
Concord Blue Energy	Chips	< 1 MW	multiple MW	http://www.concordblueenergy.com/	Germany	Gasification
Cortus	Chips	500 kW	5 MW	http://www.cortus.se/index.html	Estonia	
Dall Energy	Chips	2MW	9MW	www.dallenergy.com/Projects.52.aspx	Denmark	Gasification
Diversified Renewable Energy	Chips,	250 kW		http://www.diversifiedtn.com/t-	Tennessee	Gasification
Echo Energy Group	Chips	?	?	http://www.echoenergygroup.net/gasification.php	South Carolina, USA	Gasification
ElectraTherm	Waste heat	35kWe	110kWe	http://electratherm.com/		
Elementa Group	Chips	5MW	300MW	http://www.elementagroup.com/MunicipalSolutions/Comme	Ontario	Gasification
Enerone	Chips, Pellets	2.5 MW	3 MW		South Korea	Combustion
Ensyn	Chips			http://www.ensyn.com	Wilmington, Delaware	Gasification
EntiMos	Chips	300 kWe	470 kWe	http://www.entimos.fi/inenglish.htm		
FICFB		10 kWth	8 MW th	http://www.ficfb.at/	Gussing, Austria	
Foster Wheeler Global Power	Chips, Hog	205 MWe	205 MWe	http://www.fwc.com/getmedia/ebd91004-e144-4bc1-8a40-		
Guascor Power		670kWe	2MWe	http://www.guascorpower.com/eng/bioenergia_definicion.ph	Spain	Gasification
Hurst	chips, etc.	3.4 MMBTUh	60 MMBTUh	http://www.globalenergychicago.com/,		Combustion
Husk Power Systems	Chips	25kW	100kW	http://www.huskpowersystems.com/innerpagedata.php?pag	India	Gasification
ICM Inc.	Chips, Pellets	3MW	16MW	http://www.icminc.com/products/advanced-gasification.html		
Infinite Energy	Chips,	10kWe	1000kWe	http://www.infiniteenergyindia.com/biomass-gasifiers.html	India	Gasification
Intellergy				http://www.intellergy.com/		Gasification
Linear Power			250kW	http://www.powerhearth.net/	New Zealand	Gasification
Maxxtec - ORC	Waste heat	5 kWe	2 Mwe	http://www.maxxtec.com/en/		
Milena Technology	Chips	30kW	12mW	http://www.milenatechnology.com	Netherlands	Gasification
Mothermilk	Chips	250 kW		http://www.mothermik.de/engl/prod-1holzver-e.html	Pfalzfeld, Germany	Gasification
MSW Power	Chips	72 kWe		http://www.mswpower.com/Products/GEM/Specifications.as	Acton, MA	Gasification
Netpro	Chips	12kWh	400kWh	http://www.netprorenewable.com	Indi	Gasification
New Range Power	Chips	250 kWe	250 kWe	http://www.newrangepower.com/about-nrp.html	Bellingham	Gasification
Nexterra	Chips, Hog	2 MWe	15 MWe	http://www.nexterra.ca/files/gasification-technology.php		
NRG Consultants	Chips, Pellets	5kW	29kW	http://www.holzvergaserwerkstatt.de/#!biomass-power/cod	Germany	Gasification
OkoFen	pellets					
PHG Energy	Chips,			http://www.phgenergy.com/company		
Planet Green Solutions	Chips	20kWe	120kWe	http://www.planetgreensolutions.com	Florida, USA	Gasification
Powerhouse Energy (Pyromex)		5 tons/day	25 tons/day	http://www.powerhouseenergy.net/IRM/content/home.html		Gasification
Proton Power	Chips,	250 kWe	2000 kWe	http://www.protonpower.com/	240 Sam Rayburn	
Pyroneer		6MW	6MW	http://www.dongenergy.com/pyroneer/Pages/index.aspx		Gasification
Radian	Chips			http://www.radianbioenergy.com/technology.html		
Refgas-UK	Chips	.65 MW	2MW	http://www.refgas-uk.com/		
Renewable Energy Systems		20kW	250kW	http://www.res-gasification.net/	Alabama, USA	Gasification
Repotec	Chips	2MW	20MW	http://www.repotec.at/index.php/references.html		
Sierra Energy	Chips			http://www.sierraenergycorp.com/fastox-pathfinder/	Davis, CA	Gasification
Skinner				http://www.skinnerpowersystems.net/		Combustion
Spanner	Chips	30 kW	45 kW	http://www.holz-kraft.de/en/	Germany	Gasification
Tallon Lumber	Chips			http://www.ctcleanenergy.com/Portals/0/Tallon%20RFQ%20-		
Thermogenics	Chips	300kW	6MW	http://www.thermogenics.com	Albuquerque, NM	Gasification
Thompson Spaven	Chips		90kWe	http://www.thompsonspaven.com/	UK	Gasification
TK Energi As	Chips, Pellets	125 kW	6.5 MW	http://www.tke.dk/		
Turboden ORC (Pratt & Whitney)	Chips	200 kW	15 MW			ORC technology
Valmet	Chips	20	200	http://www.valmet.com/		
Victory Gasworks	Chips, Pellets	1kWe	5 kWe	http://gasifier.wpengine.com/		
Volter	Chips	30 kW	40 kW	http://www.volter.fi/en/page/2	Kempele Finland	
Weiss	Chips	200kWe	1MW	http://www.weiss-as.dk/side5619-aid-3887-mid-190-params-	Denmark	Gasification
Xylowatt	Chips	1MW	1MW	http://www.xylowatt.com/		
ZeroPoint	Chips	3.6MW		http://www.zeropointcleantech.com/company	NY, USA	Gasification
Zilkha	Chips, pellets	1.5 MW	20 MW	http://zilkha.com/		
PRM Energy		1MW	1MW	http://www.prmenergy.com/2009/09/wood-fuel-andor-	Arkansas, USA	Gasification
DESI Power	Chips			http://www.desipower.com/Activities.aspx	India	Gasification
	Chips	1MW	15MW	http://www.bioenergy-noe.com/?_id=191	Finland	Gasification
Borealis Wood Power Corp.				http://www.borealiswoodpower.com/		

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Bay Area Biosolids to Energy Coalition (BAB2E)

Coalition of Nineteen Bay Area water treatment agencies looking at local sustainable biosolids management including energy utilization.

- Commercial Proposals Being Considered:
  - MaxWest
  - SCFI
- Technology Research and Demonstration Projects:
  - Chemergy
  - City of San José

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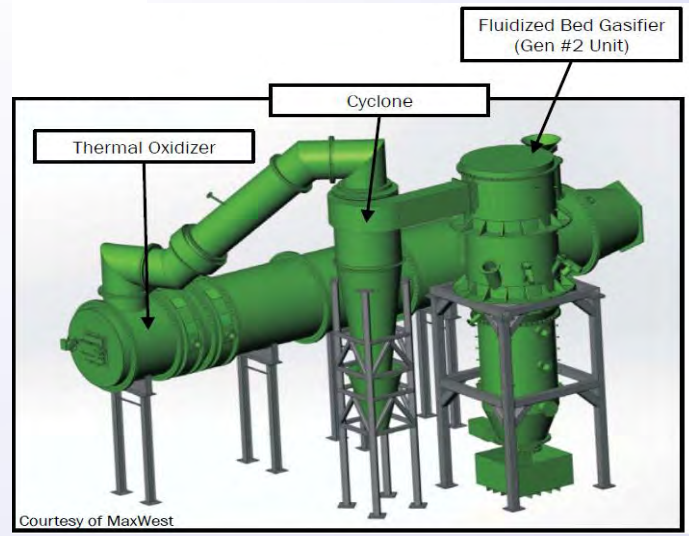
BAB2E Commercial Proposals Being Considered:

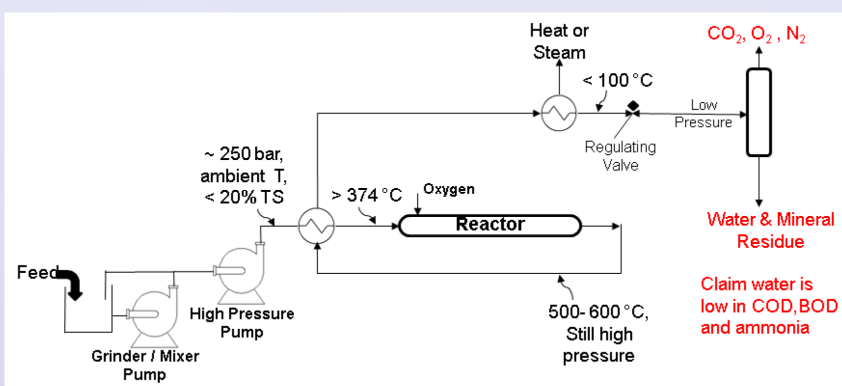
MaxWest:

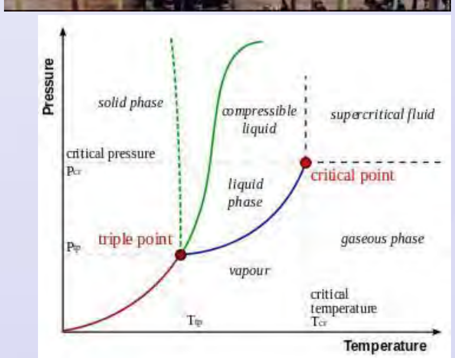
- Fluid bed gasifier-close-coupled-combustion
- Combustion heat used to dry feedstock (biosolids) to about 10% moisture
- Zero net energy disposal of biosolids (claim)



SCFI (Cork, Ireland)

- Super Critical Water Oxidation Process--"AquaCritox"
- Heat or steam product,CO2 and inert solid





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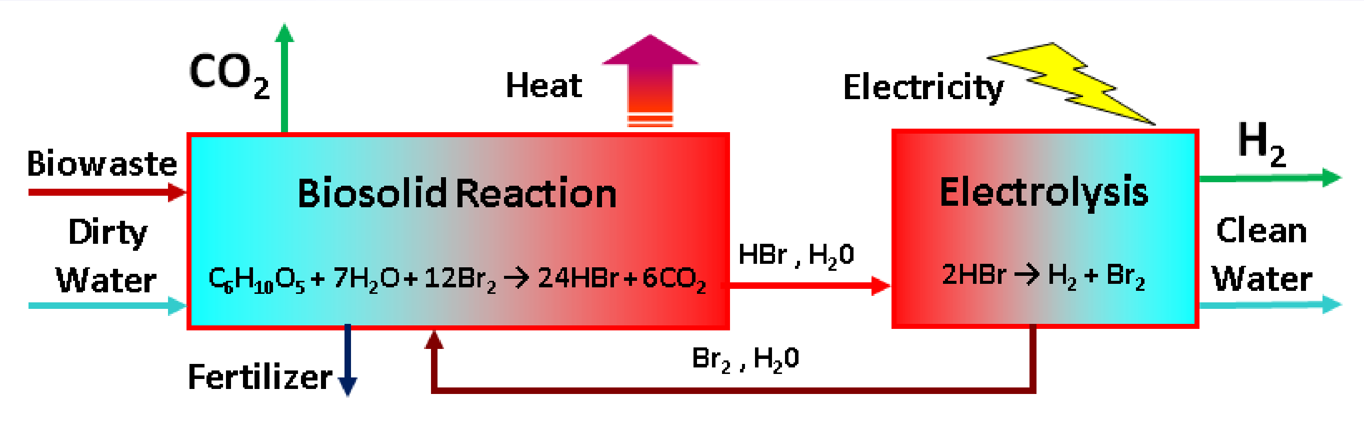
BAB2E Technology Research and Demonstration Projects:

Chemergy HyBrTec demonstration (Commission Funding)



Electrochemical conversion

- Product: Hydrogen Gas
- Biosolids ($C_6H_{10}O_5$) + aqueous bromine → acid (HBr) + CO_2 + heat
- HBr is electrolyzed → Hydrogen + H_2O + Br_2

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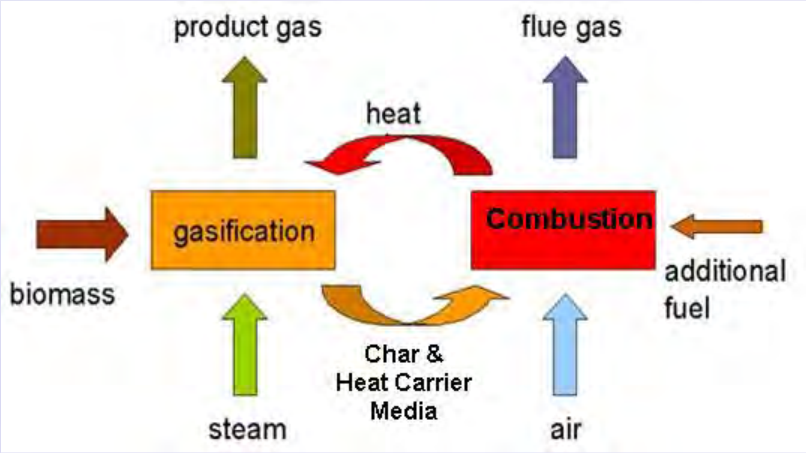
BAB2E Technology Research and Demonstration Projects:

City of San José (Commission Funding)

- Gasification to demonstrate production of fuel-quality syngas from mixtures of:
  - Clean urban wood residue &
  - Biosolids
- Concord Blue Energy (Blue Tower) Technology
- Indirect heat steam gasification



Blue Tower Pilot Plant, Herten, Germany

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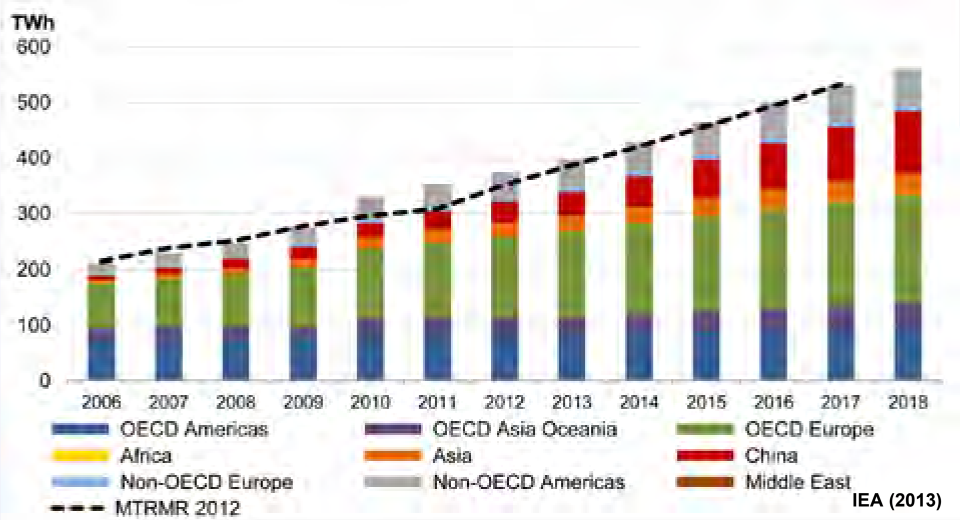
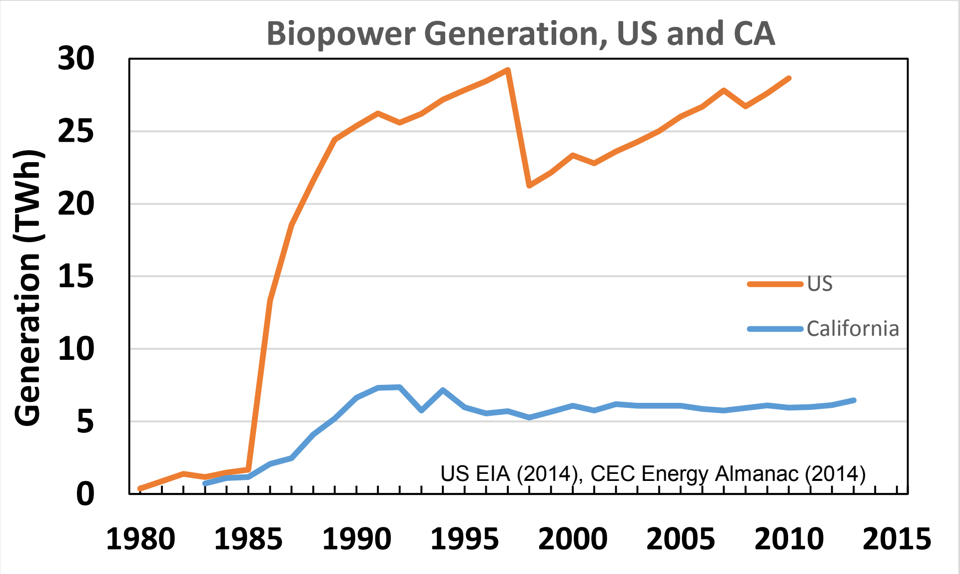
State of Bioenergy (solid fuel and biogas power)

- ~ 400 TWh/y biopower generated in the world
  - Project Increase (IEA, 2013)



- ~ 28 TWh/y biopower US

- 6 TWh/y in California
  - ~ stable for 20 years
  - Some policy in place to encourage new capacity
  - Other policies tend to hinder



Biopower Facilities in California

	Capacity (MW)	Facilities
Solid Fuel (woody& ag.)	574.6	27
LFG Projects	371.3	79
WWTP Facilities	87.8	56
Farm AD	3.8	11
FoodProcess/Urban AD	0.7	2
Totals	1038	175
Solid Fuel (MSW)	63	3

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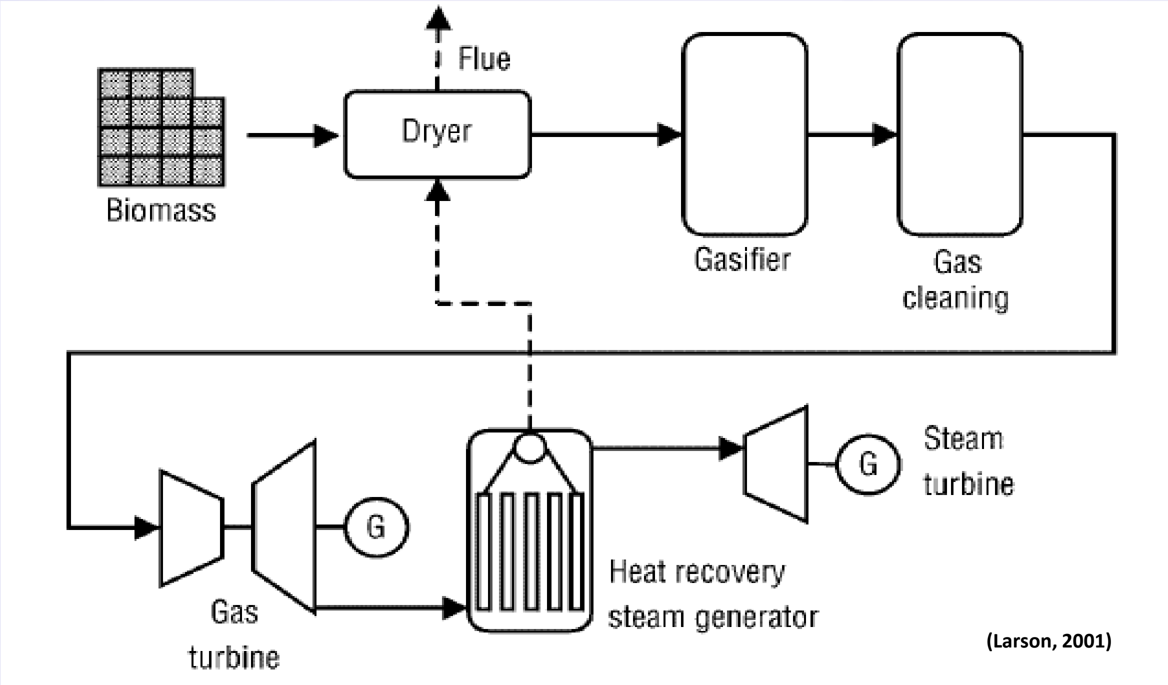
Biomass Integrated-Gasification-Combined-Cycle (BIGCC)

- Here, BIGCC refers to Gasifier integrated with Gas Turbine generator followed by Steam Rankine cycle (as in figure)
- Other configurations include gasifier integrated with:
  - Reciprocating Engine-Generator followed by Steam or Organic Rankine
  - Fuel Cell in combination with Gas Turbine (burning fuel cell "tail gas")
  - Fuel Cell followed with Steam / Organic Rankine



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Biomass Integrated-Gasification-Combined-Cycle (BIGCC)

- Potential for higher efficiency [30-40%] at 20-100+ MW scale
  - Conventional solid-fuel combustion efficiencies are in 12-25% (5- 50 MW)
- Improved emissions
  - Permitted NOx limits for existing solid fuel biomass facilities range from ~1 to 5 lb./MWh (weighted average is 2.3 lb./MWh)
  - Doepending on gasifier configuration, BIGCC NOx could approach "central station power plant emission standards" (0.07 lb./MWh for NG CC)

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Biomass Integrated-Gasification-Combined-Cycle (BIGCC)

- IGCC fueled by coal, petcoke and other petroleum co-products operate in the US and worldwide
- Emerging for biomass
  - 6 MW Pilot Scale Demonstrated using biomass in 1990's (Värnamo, Sweden)
  - A 5.5. MW Recip. Engine – steam turbine CC demonstrated in China ~ 2005
- Cost of electricity projected \$0.10 – 0.20/kWh. Competitive w/ new Solid-Fuel Combustion Power

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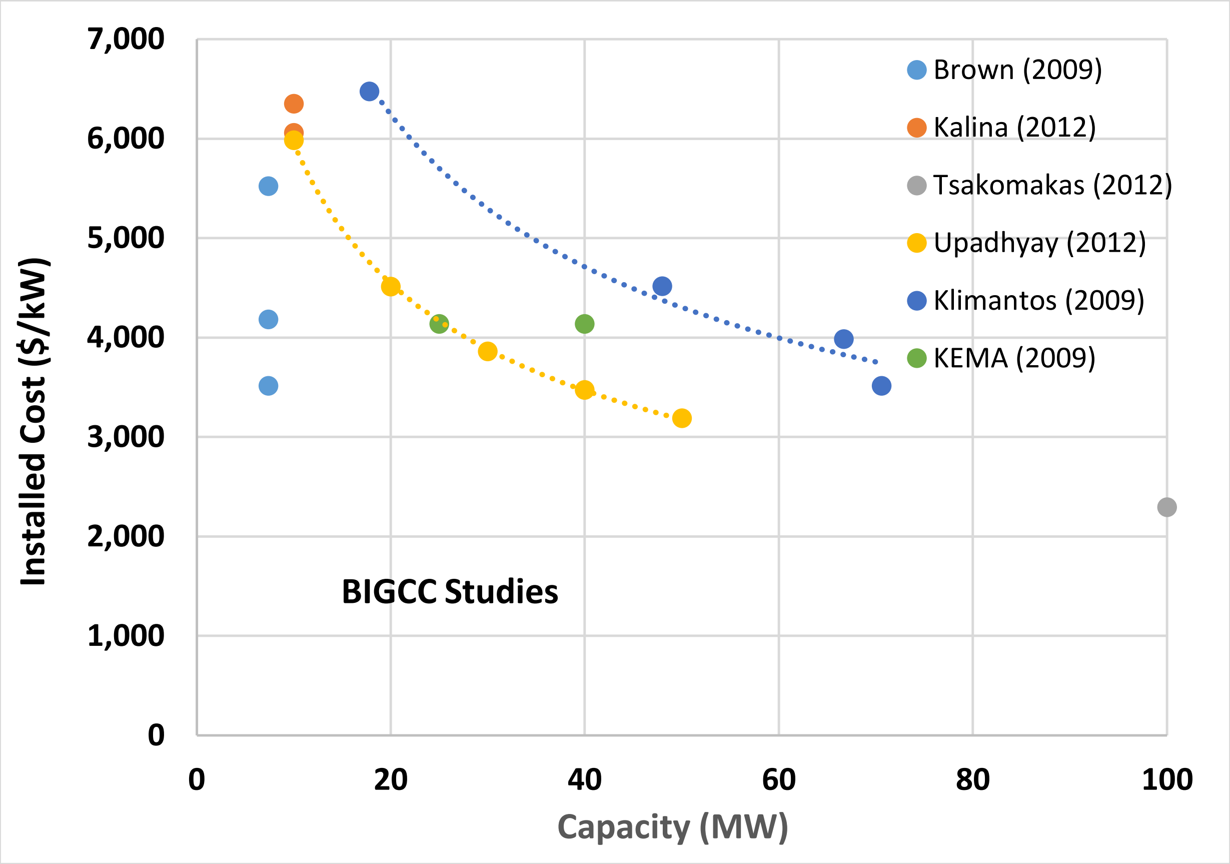
Biomass Integrated-Gasification-Combined-Cycle (BIGCC)

Installed cost estimates from techno-economic modeling literature*



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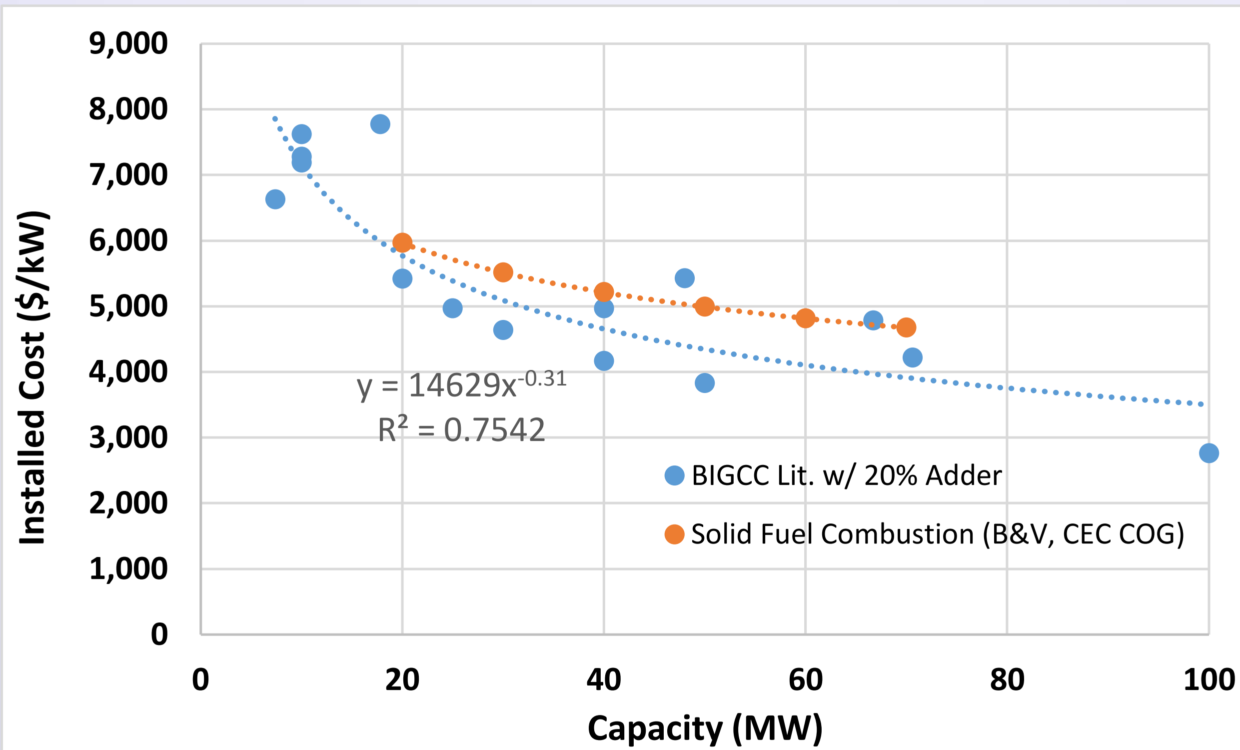
* Yr. 2014 $ using CPI inflation and $1.4 per Euro

Biomass Integrated-Gasification-Combined-Cycle (BIGCC)

- Develop a cost curve from the BIGCC literature including a 20% California "adder"*
- Also shown is conventional biomass combustion installed costs (Black and Veatch estimates and CEC cost of generation model)
- Suggests BIGCC would be competitive with new-build conventional combustion simple cycle systems



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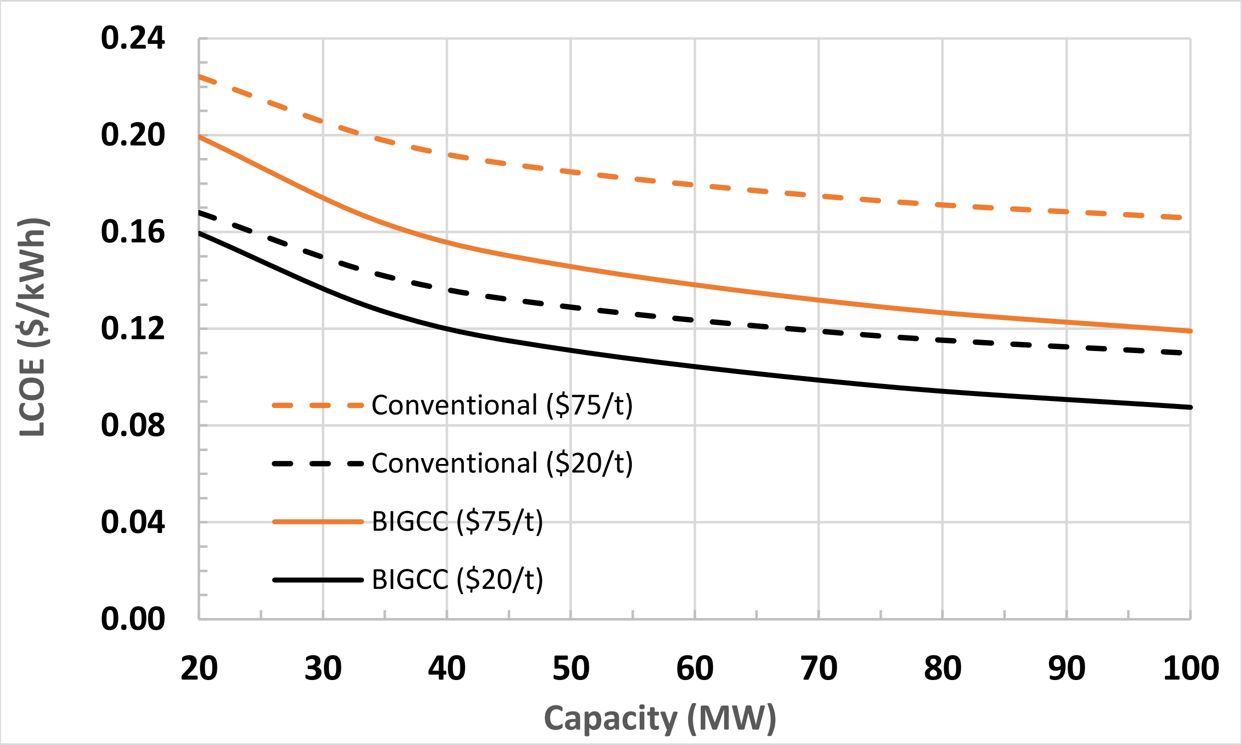
* 20% California cost premium is consistent with engineering design and consulting firm observations

Biomass Integrated-Gasification-Combined-Cycle (BIGCC)

LCOE, Conventional & BIGCC for two fuel costs
($20/BDT and $75/BDT)



- Cost of electricity projected $0.10 – 0.20/kWh. Competitive w/ new Solid-Fuel Combustion Power

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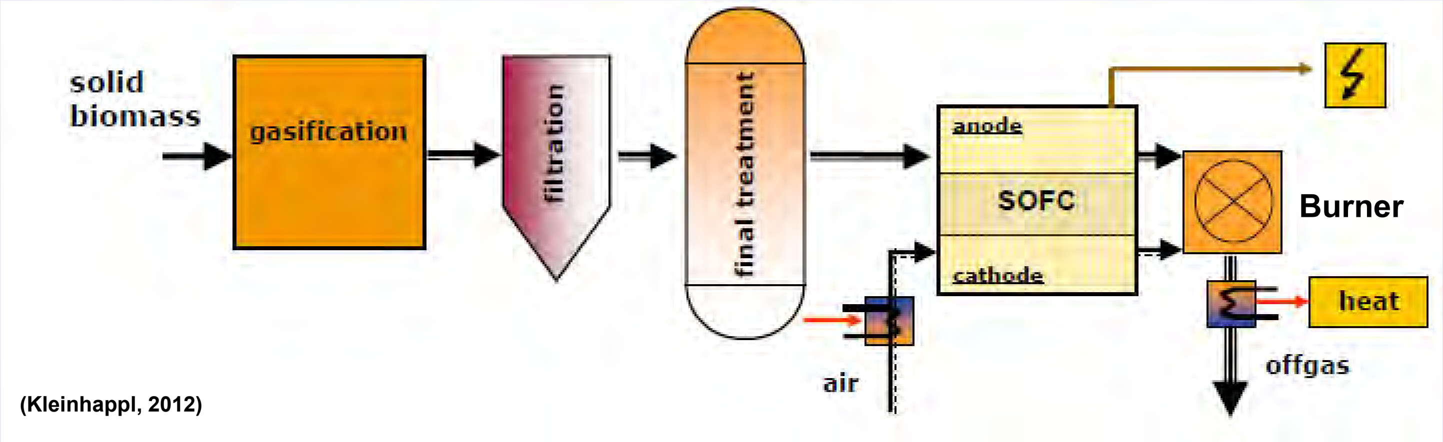
Biomass Integrated-Gasification-Fuel Cell (BIGFC)

Basic Components (simple cycle)

- Gasifier
- Appropriate gas cleaning components
- Fuel cell (internal reforming) for power
- Burner to consume unused gas, produce heat

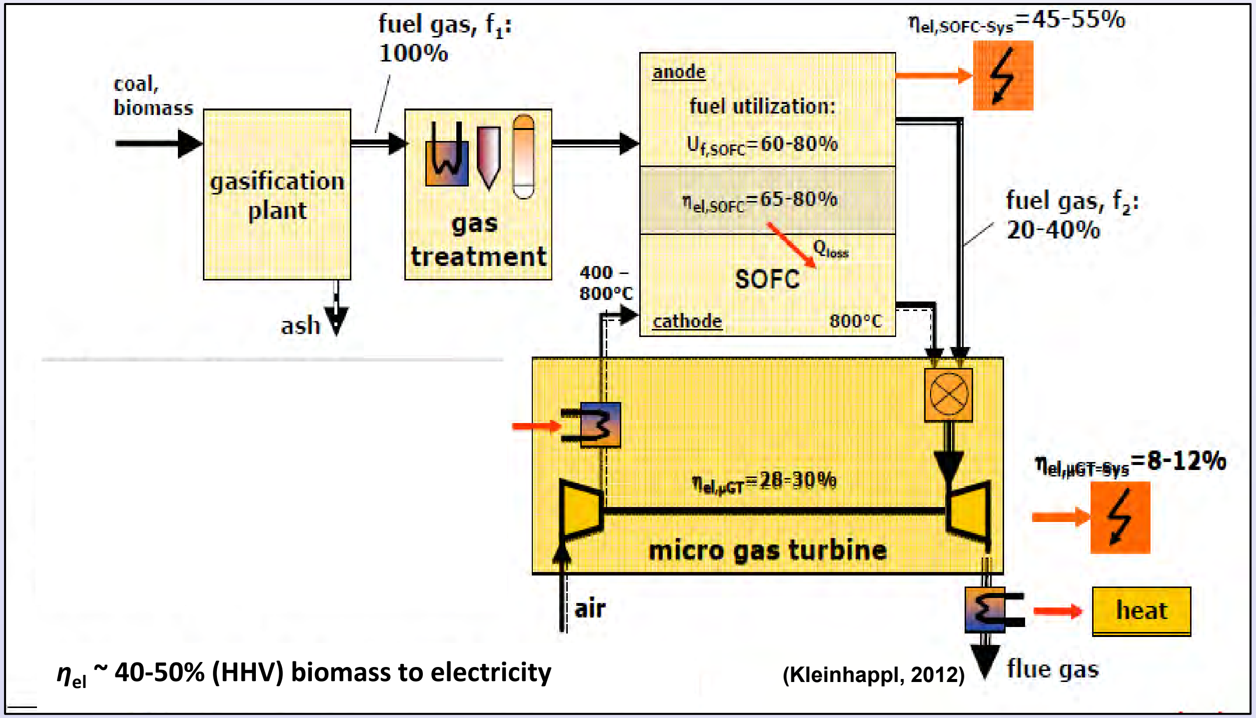


(Kleinhappl, 2012)

Biomass Integrated-Gasification-Fuel Cell (BIGFC)

Combined Cycle Concept (BIGFC- Gas Turbine)

- Insert gas turbine (microturbine) in place of burner in the simple cycle configuration



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Biomass Integrated-Gasification-Fuel Cell (BIGFC)

- Potential for high efficiency & very low emissions at small scale: <1 - ~ 10 MW
  - 20-40 % simple cycle (Fuel Cell only)
  - 40-50 % combined cycle (FC-GT)
- Solid Oxide Fuel Cell seems to be most promising application
  - High temperature, internal reforming (in addition to H2, can oxidize CO and light hydrocarbons)
  - Somewhat tolerant to low quality gas (compared to other Fuel cell types)

impurity	crude gas	SOFC required
Particles, aerosols	10,000 – 40,000	< 1.2
tar	1,500 – 2,500	1,500 – 3,000
ammonia	1,000 – 2,000	< 3,800
hydrogen sulphide	100 - 300	< 5

(Kleinhappl, 2012)

- Lab Scale developmental
- **High cost of electricity projected initially**

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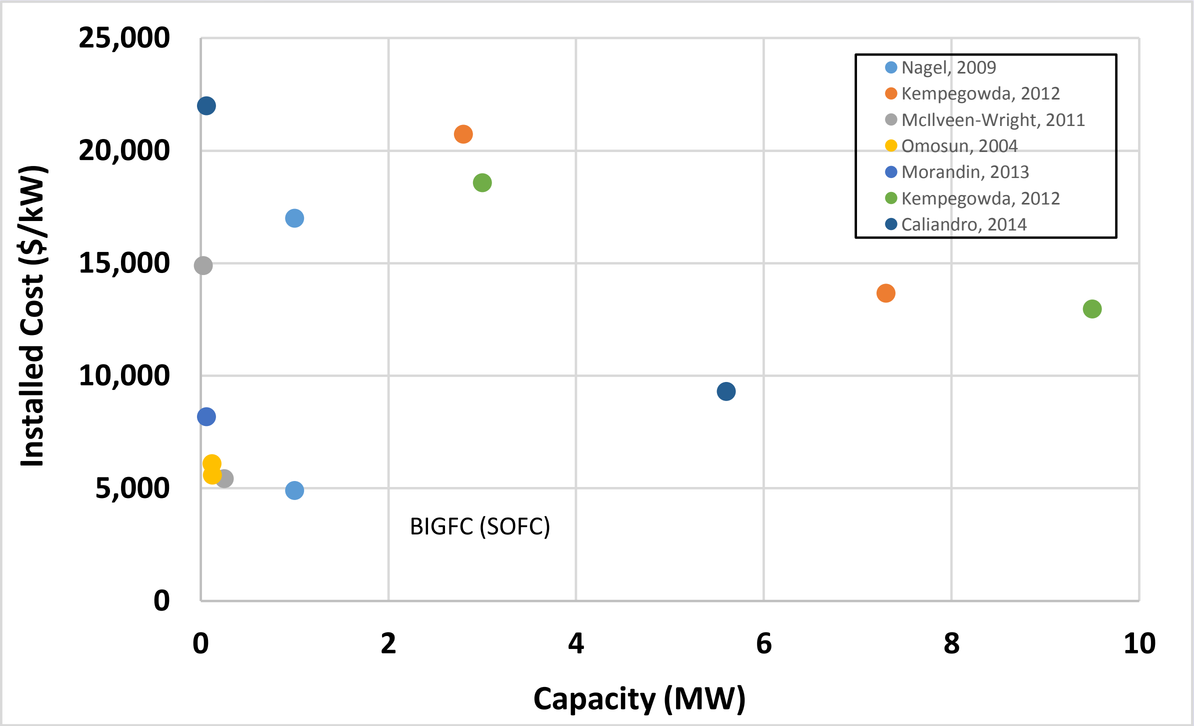
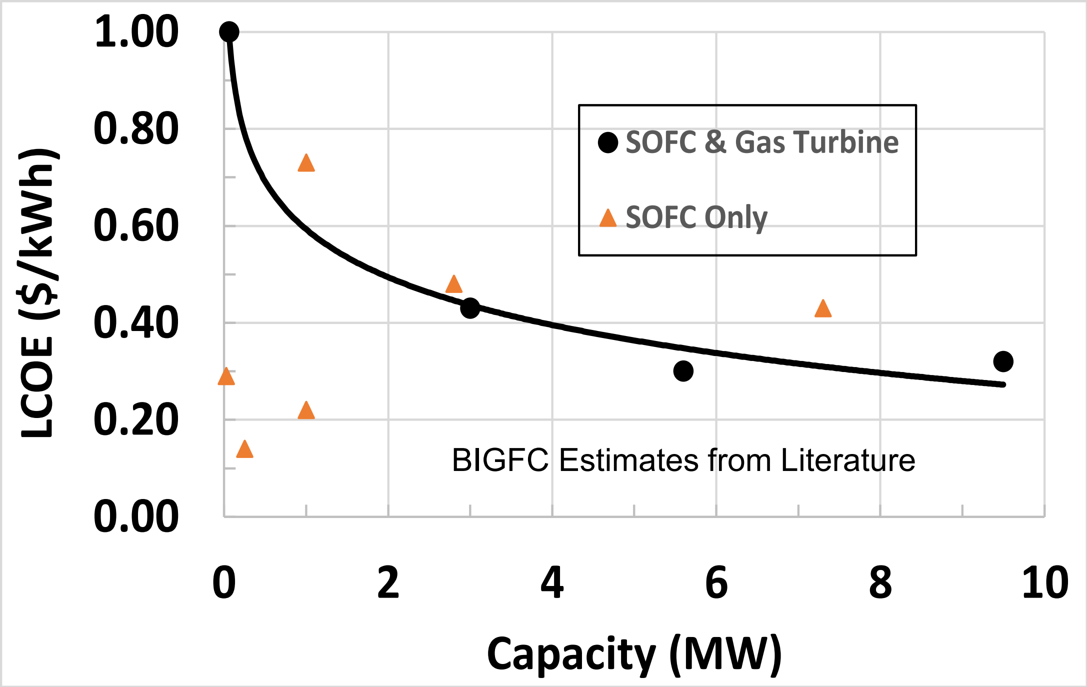
Biomass Integrated-Gasification-Fuel Cell (BIGFC)

- Installed Costs (modelling studies)
  - $5,000 - $23,000 / kW installed
  - Wide variation in the literature



Biomass Integrated-Gasification-Fuel Cell (BIGFC)

- High cost of electricity projected, at least initially
  - $0.20 -1.00/ kWh LCOE
  - Maybe economy of scale, weak trend in these data.
- Natural gas fueled SOFC stationary power not yet commercial
  - NETL estimates that 25 x 1 MW SOFC natural gas installations are needed in order for “learning” to lower costs to commercial range



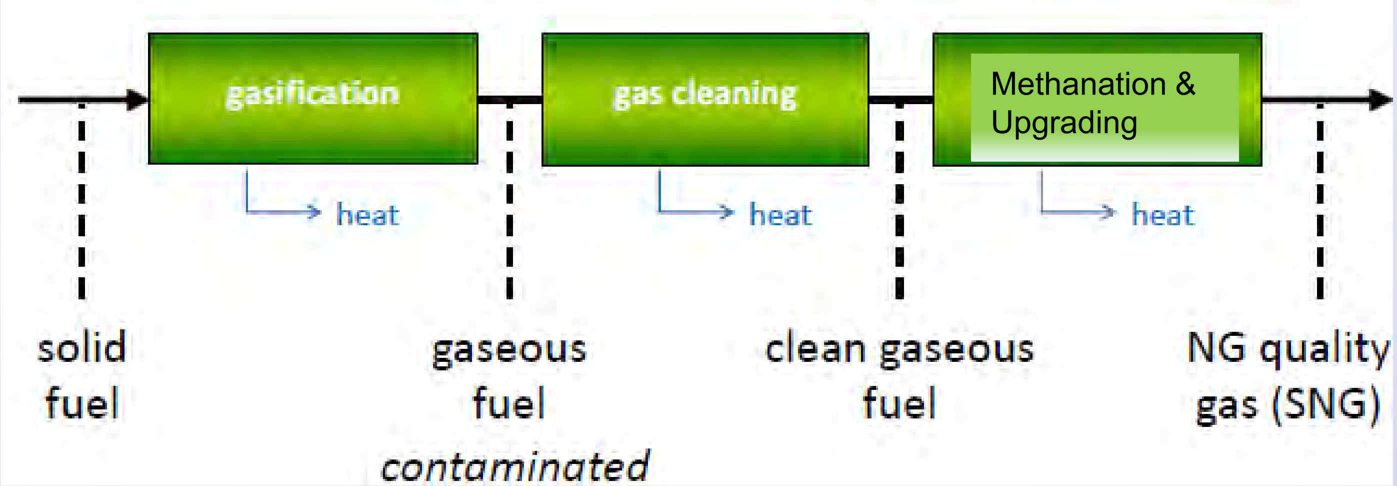
Renewable Synthetic Natural Gas (RSNG)

Biomethane via thermal gasification pathway

- Thermal gasification,
- Appropriate gas cleaning
- Reform to methane,

$$CO + 3H_2 <=> CH_4 + H_2O$$
$$CO_2 + 4H_2 <=> CH_4 + 2H_2O$$
$$CO + H_2O <=> H_2 + CO_2$$

- Upgrade to NG quality (remove CO2, H20)



Renewable Synthetic Natural Gas (RSNG)

- Thermal Efficiency ~ 65% (biomass to SNG)
- Improved efficiency and emissions for biopower applications
  - Overall biomass-to-electric energy eff. would be ~30- 33% (in a natural gas combined cycle plant, η= 50%)
  - Emissions equivalent to natural gas power plant
- Some hydrogen remains in gas after methanation process
  - Up to 5% H_2 in SNG has been reported in literature
  - Natural gas pipeline standards in North America have low limits for H_2 (typically < 0.1%)

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Renewable Synthetic Natural Gas (RSNG)

- 20MW$_{gas}$ RSNG facility commissioning in Gothenberg Sweden "GoBiGas"
  - Uses the "Güssing" gasifier technology (FICFB, indirect steam gasification)
- 100 MW$_{gas}$ Phase II planned for 2016
- 200 MW$_{gas}$ Plant in design stage by E.ON called "Bio2G"

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Renewable Synthetic Natural Gas (RSNG)

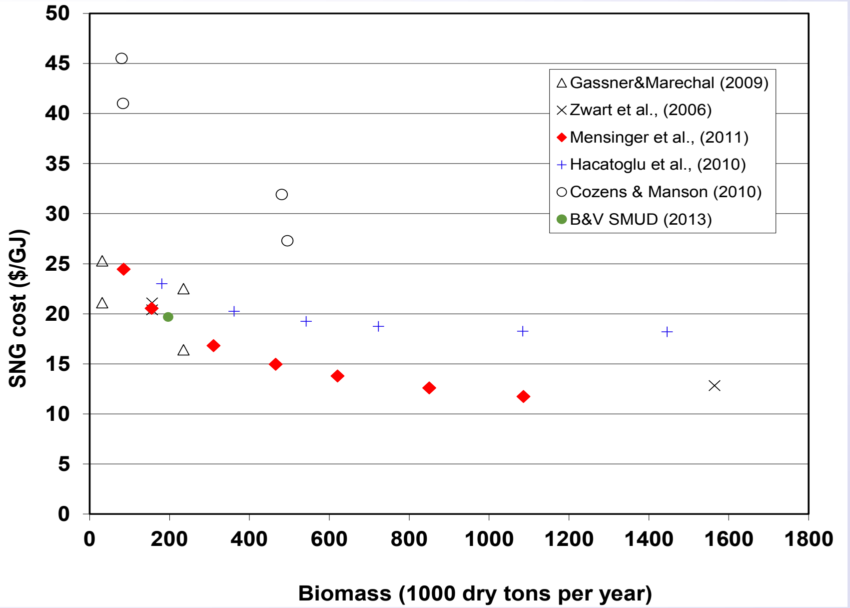
Renewable Gas Production Costs ($/GJ)
(1 GJ ≈ 0.95 MMBtu)

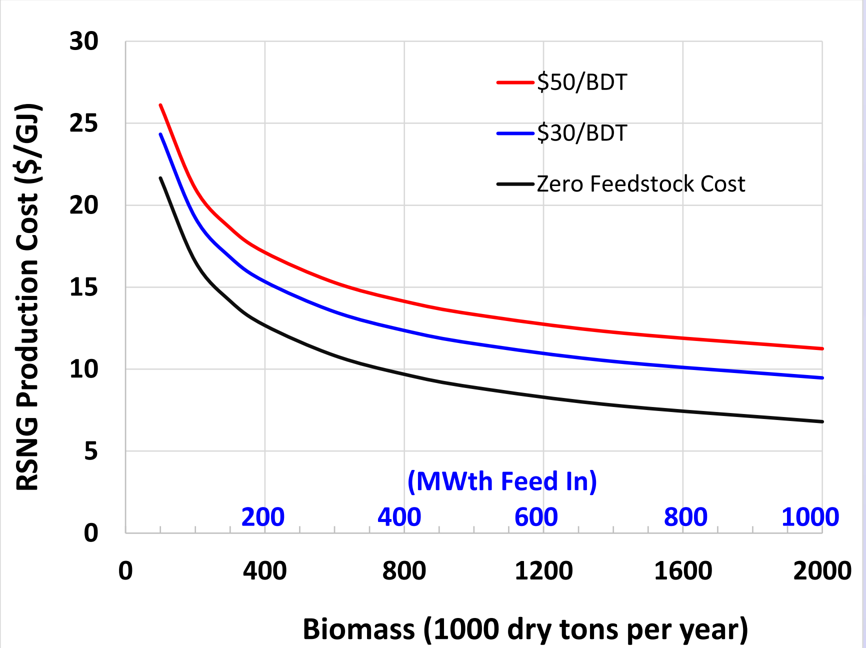
- Derive from techno-economic studies in literature
- Convert to 2014 $

Estimate here is

- $10 / MMBtu at very large scale (2 million dry-tons per year input, ~ 650 MW gas production)
- $20 / MMBtu @ 200,000 t/y biomass (65 MW gas production)

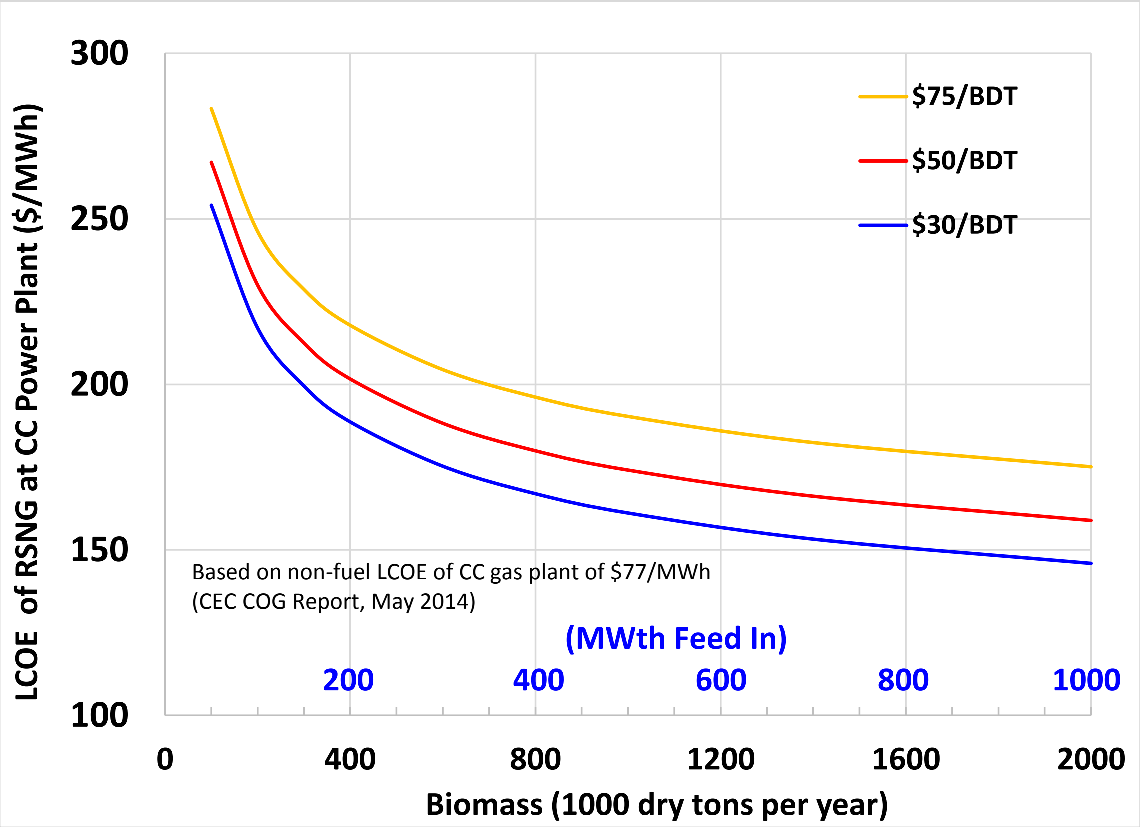
Natural gas: ~5 – 7 $/MMBtu





Renewable Synthetic Natural Gas (RSNG)

- LCOE: 150 – 250 $/MWh in a combined cycle natural gas power plant (assuming $77/MWh non-fuel cost at NG CC plant)



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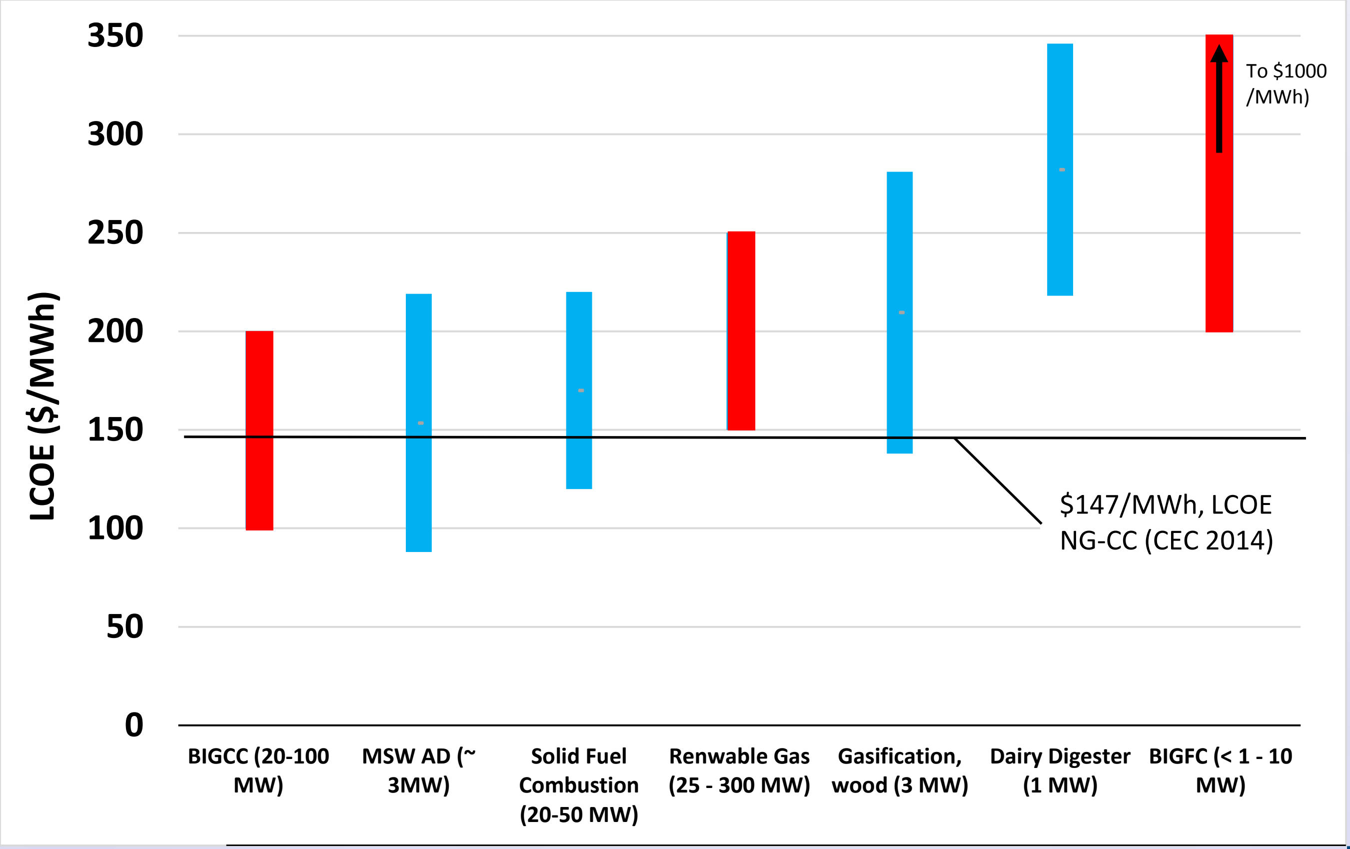
LCOE Summary

- LCOE Summary:
  - RED bars : Advanced systems reviewed in project
  - BLUE bars: Conventional systems



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Research Recommendations

- Costs generally need to be reduced across all biopower technologies
  - Research will help
  - Learning through building capacity of advanced systems will help
- Reliable gas cleaning and tar reforming methods need to be demonstrated: this will improve all biomass gasification applications
  - Small to Large
  - Power or syngas/fuels production
- For renewable natural gas via thermal gasification, H_2 in final product issue needs to be explored and solved
  - Remove or reduce H_2 and/or
  - Adjust natural gas pipeline specifications to allow higher concentration
- If BIG-FC systems are of interest, develop or expand basic research programs in US and California in this area (almost all literature is from Europe)

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Task 8: Comparative Assessment of Technology Options for Biogas Clean-up

Matthew Ong

California Biomass Collaborative

University of California, Davis

Research Results Forum for Renewable Energy Technology and Resource Assessments

September 3, 2014

History of CA Biomethane Pipeline Injection

1970s – Vinyl chloride was identified as a potent gaseous carcinogen

1980s – Increasing vinyl chloride concerns with rise of PVC industry

1988 – AB 4037 (Hayden)

- Set vinyl chloride limitations for landfill gas being injected into pipelines; heavy fines for noncompliance
- IOUs responded by disallowing landfill gas

2012 – AB 1900 (Gatto)

- Opens landfill gas / biomethane access to IOU pipelines, given certain conditions

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AB 1900 (Gatto)

- Investigate biogas constituents of concern
- Develop biomethane standards
- Establish monitoring and testing requirements
- Require CPUC to adopt pipeline access rules to ensure nondiscriminatory open access to IOU gas pipeline systems
- Require IOUs to comply with standards and requirements, and provide access to common carrier pipelines.

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Biogas is comprised of methane and carbon dioxide, but also can contain various impurities

- Sulfur compounds (H_2S, Mercaptans, COS, …)
- Siloxanes
- Nitrogen & Oxygen
- Volatile organic compounds
- Halocarbons
- Moisture
- Particulates

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Biogas characteristics vary depending upon the source

	Landfill	Wastewater Treatment Plant	Agricultural Digester	MSW Digester	Gasifier
Higher Heating Value (Btu/cf)	**208 – 644**	**550 – 650**	**550 – 646**	**N.A.**	**94 – 456**
Temperature (°C)	10 – 30	30 – 40	40 – 60	N.A.	N.A.
Methane (%)	20 – 70	55 – 77	30 – 75	50 – 60	1 – 20
Carbon Dioxide (%)	**15 – 60**	**19 – 45**	**15 – 50**	**34 – 38**	**10 – 30**
Hydrogen Sulfide (ppm)	**0 – 20,000**	**1 – 8,000**	**10 – 15,800**	**70 – 650**	**80 – 800**
Nitrogen (%)	0 – 50	< 8.1	0 – 5	0 – 5	40 – 70
Oxygen (%)	0 – 10	0 – 2.1	0 – 1	0 – 1	
Hydrogen (%)	0 – 5	0	0	N.A.	10 – 60
Ammonia	0 – 1%	0 – 7 ppm	0 – 150 ppm	N.A.	0.1 – 0.37%
Carbon Monoxide (%)	0 – 3	0 – 0.01		N.A.	10 – 45
Siloxanes (ppm)	0.1 – 4	1.5 – 10.6	0 – 4	N.A.	N.A.

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ARB/OEHHA 12 Constituents of Concern

Constituent of Concern	Risk Management Levels (ppmv)			Source-Specific Constituents of Concern		
	Trigger Level	Lower Action Level	Upper Action Level	Landfills	POTW	Dairy
Carcinogenic Constituents of Concern						
Arsenic	0.006	0.06	0.15	✔		
p-Dichlorobenzene	0.95	9.5	24	✔	✔	
Ethylbenzene	6.0	60	150	✔	✔	✔
n-Nitroso-di-n-propylamine	0.006	0.06	0.15	✔		✔
Vinyl Chloride	0.33	3.3	8.3	✔	✔	
Non-carcinogenic Constituents of Concern						
Antimony	0.12	1.2	6.1	✔		
Copper	0.02	0.23	1.2	✔		
Hydrogen Sulfide	**22**	**216**	**1,080**	✔	✔	✔
Lead	0.009	0.09	0.44	✔		
Methacrolein	0.009	3.7	18	✔		
Alkyl Thiols (Mercaptans)	12	120	610	✔	✔	✔
Toluene	240	2,400	12,000	✔	✔	✔

ARB/OEHHA
12 Constituents of Concern

- Unique to California
  - Technology suppliers need to test systems for treatment of new contaminants
- Added to PG&E, SoCalGas, SDGE, and SWGas gas tariffs
- IOUs additionally hold biomethane to prior (except SWGas) natural gas quality standards
  - PG&E Gas Rule No. 21
  - SoCalGas Rule No. 30
  - SDGE Rule 30
  - SWGas Rule No. 22 (new)

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Investor-Owned Utility Natural Gas Pipeline Injection Stds

	PG&E	SoCalGas	SDGE	SWGas
Higher Heating Value (Btu/cf)	**750 – 1150 (990 - 1050)***	**990 - 1150**	**990 -1150**	**950 - 1150**
Temperature (°F)	60 - 100	50 - 105	50 - 105	40 - 120
Carbon Dioxide (%)	**1**	**3**	**3**	**2**
Water Vapor (lb/MMscf)	7	7	7	7
Hydrogen Sulfide (ppm)	**4**	**4**	**4**	**N.A.**
Mercaptans (ppm)	8	5	5	N.A.
Total Sulfur (ppm)	17	12.6	12.6	34
Total Inerts (%)	4	4	4	4
Nitrogen (%)	N.A.	N.A.	N.A.	3
Oxygen (%)	0.1	0.2	0.2	0.2
Hydrogen (%)	0.1	0.1	0.1	0.1
Ammonia (%)	0.001	0.001	0.001	0.001
Siloxane (mg/m³)	0.01 – 0.1	0.01 – 0.1	0.01 – 0.1	0.01 – 0.1

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Source vs End Use Quality

Compound	Landfill	Wastewater Treatment Plant	Agricultural Digester	MSW Digester	Gasifier
HHV (Btu/cf)	208 – 644	550 – 650	550 – 646	N.A.	94 – 456
CO_2 (%)	15 – 60	19 – 45	15 – 50	34 – 38	10 – 30
H_2S (ppm)	0 – 20,000	1 – 8,000	10 – 15,800	70 – 650	80 – 800

	PG&E	SoCalGas	SDGE	SWGas
HHV (Btu/cf)	750 – 1150 (990 - 1050)	990 - 1150	990 -1150	950 - 1150
CO_2 (%)	1	3	3	2
H_2S (ppm)	4	4	4	

- Need to remove contaminants
- Need to increase HHV
  - Accomplished by removing CO_2

Source vs End Use Quality

Compound	Landfill	Wastewater Treatment Plant	Agricultural Digester	MSW Digester	Gasifier
HHV (Btu/cf)	208 – 644	550 – 650	550 – 646	N.A.	94 – 456
CO_2 (%)	15 – 60	19 – 45	15 – 50	34 – 38	10 – 30
H_2S (ppm)	0 – 20,000	1 – 8,00	10 – 15,800	70 – 650	80 – 800

	PG&E	SoCa	SDGE	SWGas
HHV (Btu/cf)	750 – 1150 (990 - 1050)	990 -	990 -1150	950 - 1150
CO_2 (%)	1	3	3	2
H_2S (ppm)	4	4	4	

- Removing contaminants → Cleaning
- Removing CO_2 → Upgrading

Contaminants Removal – Biogas Cleaning Techniques

- Adsorption
  - H_2S, ($VOCs$), (NH_3), (Siloxanes), (Moisture)
- Water Scrubbing
  - H_2S, VOCs, NH_3, Siloxanes
- Biofiltration
  - H_2S, VOCs, (NH_3), (Siloxanes)
- Refrigeration/Chilling
  - Moisture

Pioneer Air Systems

Robinson Group
SulfrPack

Willexa Energy
BGAK Siloxane Reduction

Enduro OdorClean 250/500

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CO_2 Removal – Biogas Upgrading Technologies

- Pressure swing adsorption
- Chemical solvent scrubbing (amines)
- Pressurized water scrubbing
- Physical solvent scrubbing (organic glycols)
- Membrane separation
- Cryogenic distillation

Most Applied

Commercially Applied

- Supersonic separation
- Industrial/Ecological lung

Emerging

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Biogas Upgrading Efficiencies

	Product CH_4 (%)	Product HHV (Btu/cf)	Product H_2S (ppm)	Methane Loss/Slip (%)	Sulfur Pre-Treatment
Pressure Swing Adsorption	95 – 98	960 – 990	< 4	1 – 3.5	Required
Amine Absorption	99	1000	< 0.2 – 8	0.04 – 0.1	Preferred / Required
Pressurized Water Scrubbing	93 – 98	940 – 990	< 1 – 2	1 – 3	Not needed / Preferred
Physical Solvent Scrubbing	95 – 98	960 – 990	< 0.1 – 20	1.5 – 4	Not needed / Preferred
Membrane Separation	85 – 99*	860 – 1000	< 1 – 4	0.5 – 20	Preferred
Cryogenic Distillation	96 – 98	970 – 990	< 0.02	0.5 – 3	Preferred / Required
Supersonic Separation	95	960	?	5	Not needed

*Multiple stages required for high CH_4 purity, but results in higher methane slip

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Majority of upgrading technologies unable to achieve specified gas quality in one stage

- Amine absorption is expensive, complicated, and requires difficult/costly O_2 pre-removal
- Other systems require more than one upgrading system / stages to reach 990 Btu/cf
  - Single upgrading systems already expensive

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Potential Solutions to HHV Issue

- Lower HHV standards

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Other U.S. Natural Gas Pipeline Injection Stds

Location / Region	North Pacific US	New Mexico	Texas	Southern US
Company	Williams Northwest Pipeline	New Mexico Gas Company	Atmos Energy	Gulf South Pipeline Company
HHV (Btu/cf)	≥ 985	950 – 1100	950 – 1100	950 – 1175
H_2S (ppm)	4	4	4	16
CO_2 (%)	2%	2%	2%	3%

Location / Region	Kansas	Michigan	Midwest US	New England
Company	Kansas Gas Service	Westcoast Energy Inc.	Northern Natural Gas	Algonquin Gas Transmission
HHV (Btu/cf)	950 – 1100	≥ 966	≥ 950	967 – 1110
H_2S (ppm)	4	4.3	4	8
CO_2 (%)	2%	2%	2%	2%

- Lower HHV than CA IOUs
- Similar contaminant standards

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Potential Solutions to HHV Issue

- Lower HHV standards
  - May have detrimental effects on end-use customer equipment (e.g., instabilities, flashbacks, flameout conditions)
  - May not be compatible with legacy systems
  - Under certain conditions, transient biomethane injection could flow well-defined for large distances (> 100 km) before mixing
- Mixing with higher HHV gases (e.g., natural gas, propane)
  - May introduce more contaminants, require additional cleaning
- Funding for suitable upgrading systems
  - Upgrading is expensive $$$

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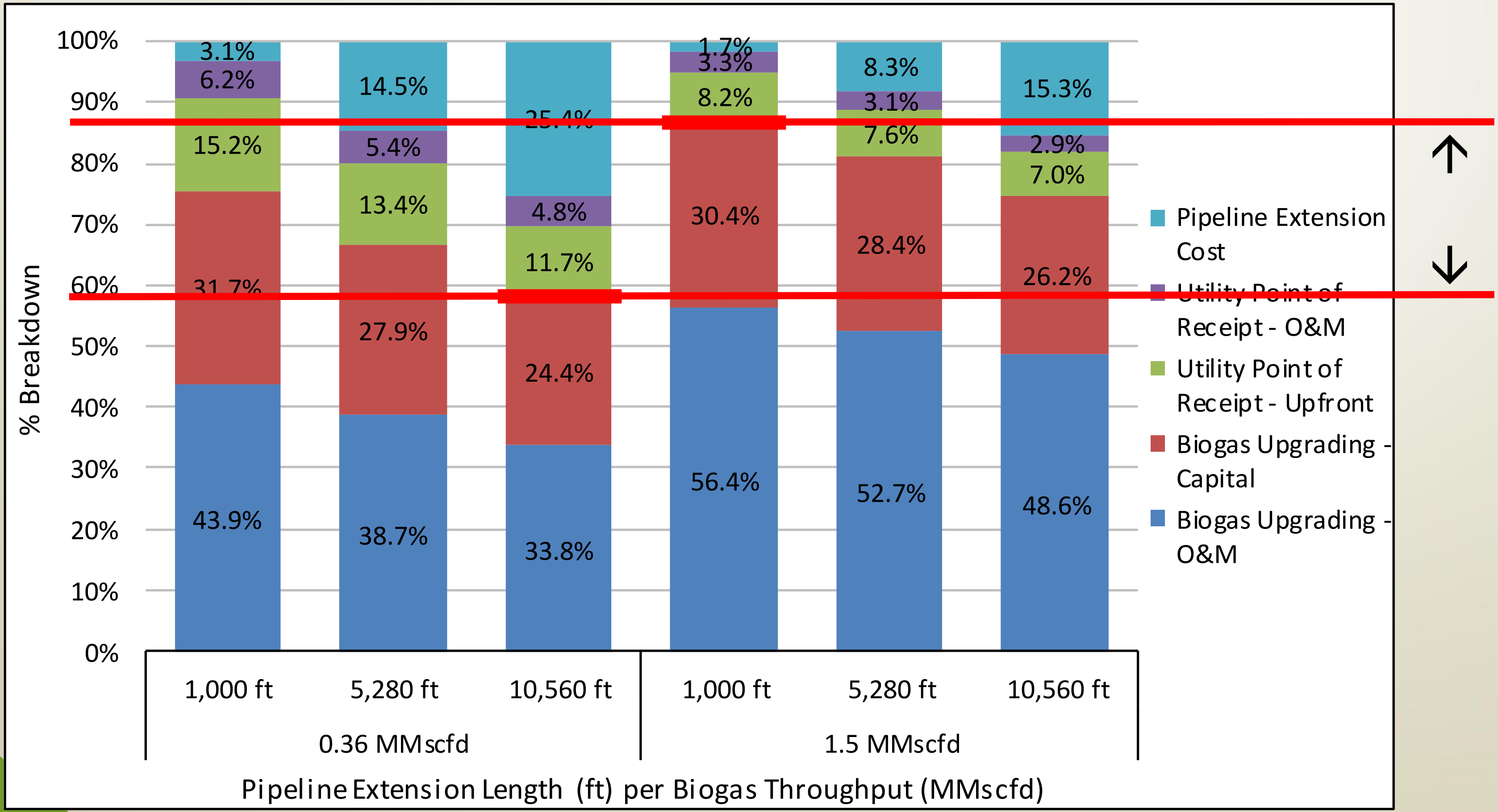
Gas upgrading represents majority of cost for pipeline injection projects



Source: Lucas, Jim (2013)

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Recommendations

- Lower HHV standards to 960 – 980 Btu/cf (?)
  - Must first investigate effects of biogas mixing through pipeline system (e.g., proper dilution ratios, mixing behavior, injection rate)
- Have 12 constituents of concern apply before being mixed with natural gas, not at point of injection
- Discuss potential funding/cost-sharing options for biogas cleaning/upgrading
  - Can model process from other countries (e.g., Germany)
  - Ongoing second phase of AB 1900 implementation

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Thank you!

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Appendix

Many options for beneficial biogas utilization

- Boilers
- Reciprocating Engines / Internal combustion
- Microturbines
- Fuel Cells
- Vehicle Fuel
- Natural Gas Pipeline Injection

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Technical limitations of biogas utilization equipment

	Reciprocating Engines	Microturbines	Fuel Cells	CNG Vehicles
Minimum HHV (BTU/cf)	**400 – 1,200**	**350 – 1,200**	**450 – 1,000**	**900**
Methane	> 60%	> 35 – 60%		> 88%
CO_2 (%)			**< 0.01 – 0.05***	
Hydrogen Sulfide (ppm)	**< 50 – 500**	**< 1,000 – 70,000**	**< 0.1 – 10**	
Total S (ppm)	< 542 – 1,742		< 0.01 – 50	< 16
Oxygen (%)	< 3		< 4	< 1
Hydrogen (%)				< 0.1
NH_3 (ppm)	< 25	< 200	< 0.05 – 200	
CO (ppm)			< 0.001 – 50	< 1,000
Chlorine (ppm)	< 40 – 491	< 200 – 250	< 0.1 – 5	< 1,000
Fluorine (ppm)	< 40	< 1,500	< 0.1 – 5	
Siloxanes (ppm)	< 2	< 0.005	< 0.01 – 100	< 1
Particle size	< 3 µm	< 10 µm	< 10 µm	

*Only for alkaline fuel cells

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Source vs End Use Quality

Compound	Landfill	Wastewater Treatment Plant	Agricultural Digester	MSW Digester	Gasifier
HHV (Btu/cf)	208 – 644	550 – 650	550 – 646	N.A.	94 – 456
CO_2 (%)	15 – 60	19 – 45	15 – 50	34 – 38	10 – 30
H_2S (ppm)	0 – 20,000	1 – 8,000	10 – 15,800	70 – 650	80 – 800

	PG&E	SoCalGas	SDGE	SWGas
HHV (Btu/cf)	750 – 1150 (990 - 1050)	990 - 1150	990 -1150	950 - 1150
CO_2 (%)	1	3	3	2
H_2S (ppm)	4	4	4	

	Reciprocating Engines	Microturbines	Fuel Cells	CNG Vehicles
HHV (BTU/cf)	400 – 1,200	350 – 1,200	450 – 1,000	900
CO_2 (%)			< 0.01 – 0.05*	
H_2S (ppm)	< 50 – 500	< 1,000 – 70,000	< 0.1 – 10	N.A.

UCDAVIS CALIFORNIA BIOMASS COLLABORATIVE

9:00	Introduction and Overview
9:15	Integrated assessment of renewable technology options
10:15	Break
10:30	Assessment of Co-located renewable generation potential
11:00	Assessment of geothermal in under-served regions
11:30	Solar heating and cooling technology analysis
Noon	Lunch
1:15	California off-shore wind technology assessment
1:45	Technical assessment of small hydro
2:15	Biomass resources and facilities database update
2:45	Break
3:00	Assessment of sustainability for new/existing biomass energy
3:30	Biomass/MSW gap assessment and tech options for biogas clean-up
4:15	**Future research recommendations**
4:45	Closing

Future Research Recommendations

Future Research Recommendations by Technology

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1. DOE SunShot set the goal of $0.06 per kWh for 2020
2. CSP-Tower and enhanced thermal storage
3. Development and production of both Silicon-based and nanostructured solar cells in the US
4. Evaluation of reduction in soft costs

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CALIFORNIA BIOMASS COLLABORATIVE

1. Costs generally need to be reduced across all biopower technologies
2. Reliable gas cleaning and tar reforming methods need to be demonstrated
3. For renewable natural gas via thermal gasification, H_2 in final product issue needs to be explored and solved
4. Develop or expand basic research programs in US and California in the area of BIG-FC.

Future Research Recommendations by Technology

UC DAVIS CALIFORNIA GEOTHERMAL ENERGY COLLABORATIVE

1. **Resource:** Higher resolution geophysical and geochemical methods to characterize and localize resources; integrated approaches for resource assessments; optimization tools to match diverse resources with applications
2. **Technology:** More efficient use of water; more efficient extraction; detailed cost, ramp rate, and market studies for flexible geothermal

UC DAVIS CALIFORNIA WIND ENERGY COLLABORATIVE

1. Optimization of wind plants (rather than turbines) to minimize LCOE.
2. Plant controls to manage ramp mitigation.
3. On-site storage systems.
4. More accurate power output forecasting models.
5. Improved short-term event prediction tools.
6. **Off-shore:** Technical, regulatory, environmental, economic barriers exacerbated in CA due to extreme off-shore water depths.

Future Research Recommendations by Technology

UCDAVIS
CALIFORNIA SMALL
HYDRO COLLABORATIVE

1. Independent testing facilities (e.g., improve understanding of performance of PATs)
2. Adaptation of existing water distribution network simulation tools needs to accommodate in-conduit small hydro specificity
3. Investigation of generators adapted to small-hydro
4. Project analysis tool adapted to in-conduit small hydro

General Observation: Future R&D Needs

- Better integration of demand side management with renewable supply (can DSM play a bigger role in off-setting the variability of intermittent renewables?)
- Evaluation of how renewable microgrids can be optimally integrated into utility infrastructure
- Assessment of the impacts of state's electric vehicle and ZNE goals on the design and management of electric infrastructure and the overall energy usage of the state (e.g., will goals result in greater electric demand? Less natural gas?)
- Develop standardized methods for optimizing an energy mix based on overall LCOE, emissions, maximized generation
- Quantification of the total benefits (including societal benefits, ancillary services, environmental impact) of all renewables to distinguish among different renewables.
- Better decision support tools for policymakers that incorporate modeling that allows for optimization of siting localized/regional renewables

General Observation: Future R&D Needs (cont'd)

- Assessment of emerging technologies that may allow renewables to provide flexible capacity needed to meet system needs.
- Develop constrained optimization models that support a strong renewable market while optimizing siting that minimizes environmental impacts.
- Coordinate resource assessment methods to achieve consistent metrics for generation outputs including storage
- Identify energy mix zones (analogous to climate zones) to optimize assessment and development efforts and streamline incentives.
- Incorporate demand data at fine spatial resolution. Opportunity to encourage distributed installations by power consumers.
- Region-specific distribution level integration studies, including smart grid technologies, vehicle-to-grid, and energy storage.

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Closing Remarks

THANK YOU!

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